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—OF THE—

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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FOR THE PROMOTION OF THE MECHANIC ARTS.

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Mining and Metallurgical Section.

Read at the Stated Meeting, held Wednesday, December 11, 1901.

Upon the Structure of Metals and Binary Alloys.

BY WILLIAM CAMPBELL, B.Sc. (Durham), F.G.S.

In the following paper the author has tried to illustrate the constitution of binary alloys by a few notes upon the structure of metals and alloys. The methods of obtaining a knowledge of the structure of metals and alloys are first discussed, then the crystalline structure of metals, the effects of strain and the effect of heat treatment are illustrated. Finally, the various groups of binary alloys are set forth and the constitution of several examples, representative of the various groups as far as possible, is shown by contrasting or rather by drawing a parallel between their cooling curves and microstructure. The whole of the original work of the paper was carried out at the Royal School of Mines, London, and in the Metallurgical Department of Columbia University.

The magnification and illumination of the various photographs of the structure of metals and alloys are represented by the symbol in the lower right-hand corner, thus: x 33. v. means multiplied thirty-three diameters and vertically illuminated; or x 16. o. means multiplied sixteen diameters and obliquely illuminated.

PRACTICAL METALLOGRAPHY.

Practical metallography may be divided into several distinct parts:

- (1) Preparation of alloys or metal to be examined.
- (2) Preparation of surface.
Cutting and polishing.
- (3) Etching the prepared surface: development of structure.
- (4) Microscopical examination.
Mounting the specimen.
Microscope and accessories.
- (5) Microphotography.

It would be out of place to do more than glance at one or two of the main points in preparing and examining sections, because the subject has been carefully treated by Stead, Le Chatelier, Sauveur and many others. One of the most important points is the preparation of the alloy or metal, because its final structure will in almost every case depend upon its rate of cooling, the uniformity of cooling, prevention of oxidation, etc., and, in the case of an alloy, upon the thorough mixing of its constituent metals when liquid. As a general rule, the slower the cooling the larger the structure. In many metals and alloys, this holds good not only during solidification, but also afterwards, because profound changes often take place long after solidification. As examples, one immediately thinks of iron and its alloys, of the bronzes and of the brasses. As an example of the necessity for guarding against oxidation, we need only consider copper and the rapidity with which its oxide diffuses through it.

There are several devices to insure slow and uniform cooling. Where a gas furnace is used, automatic cut-offs give

good results. Heycock and Neville* have invented one which will give any desired rate of cooling. It consists of a tube some 15 centimeters long by $2\frac{1}{2}$ centimeters wide, and contains an inner tube made of many layers of fine silk wound round the outside of a cylinder of coarse iron wire gauze to give it rigidity. With the exception of a line about 2 millimeters wide, running from top to bottom of the silk, the whole of this inner tube is coated with a very viscous shellac. The silk tube is open at its lower end, which dips into mercury, whilst its upper end is cemented to a glass tube connected with the gas supply from a regulator which supplies the gas at a constant pressure. The outer tube has an opening at its base, through which mercury is admitted, and an exit pipe near the top through which the gas passes to the furnace. Thus, the gas from the regulator enters the inner tube at the top, and passes through that part of it which is not covered by shellac into the outer tube and thence to the furnace. If mercury is forced into the outer tube, the gas is slowly cut off. A uniform supply of mercury is obtained from a cylinder above which is a head of water. This head of water is increased at a uniform rate by means of a constant level water dropper whose supply can be increased or decreased at will. Thus, as the head of water slowly and uniformly increases, the pressure on the surface of the mercury increases, causing it to flow into the cut-off tube and rise inside and out of the silk tube, and hence to gradually cut off the escape of gas through the unvarnished portion. In the case of alloys melting at high temperatures, we can allow sufficient gas to pass direct to the furnace by the aid of a by-pass, to keep it at the lowest temperature required, the cut-off thus becoming more efficient. Where ordinary coke fires are used a simple method can be employed which gives very good results. The alloy is made in a small crucible, and when well molten and thoroughly mixed the whole is placed in a hot, larger crucible in place in a bright fire. The outer crucible is filled with charcoal and charcoal powder, to

*Trans. Chem. Soc., 1898. No. 73, p. 714.

prevent oxidation, and the lid put on; a few pieces of hot coke are placed on top and then the fire-place is filled up with hot ashes; all dampers are closed to shut off as much draught as possible, and the whole is allowed to cool slowly. In this way the size of the structure of the alloy can be increased from ten to twenty times.

Oxidation can usually be prevented by having a good supply of charcoal on top of the alloy. In the case of many alloys whose melting-points are comparatively low, such as the tin antimony series, potassium cyanide is an excellent material to use. In the ordinary way, where very slow cooling is not necessary, some potassium cyanide is melted in a plumbago crucible. The two metals are then added, and when fluid the crucible is shaken, taken out of the furnace and allowed to cool slowly in the open air. When cool, the cyanide is washed away and the alloy taken out.

It is always necessary to thoroughly mix the constituents of an alloy, but in many cases solution and diffusion help materially to form the alloy. For example, to prepare the eutectic alloy of the copper-tin series (1 per cent. Cu, 99 per cent. Sn) the tin is first melted and the copper added in the form of foil. Although the temperature may only be between 350° and 400° C., the tin rapidly dissolves the copper, which diffuses uniformly throughout the whole mass. In most cases, if the whole contents of the crucible be liquid, a good shake of the crucible produces a uniform alloy. In some cases, however, as for instance the aluminium-bronzes, shaking or even stirring does not always produce a uniform alloy. It is then best to cast the alloy and break it up into small fragments or to granulate it and remelt till the desired result is obtained.

Having obtained our metal or alloy, the next process is to obtain a suitable piece to polish. A convenient size is one from $\frac{1}{2}$ inch to 1 inch in diameter and about $\frac{1}{8}$ inch thick. In the case of very hard and brittle metals or alloys, a fragment is broken off of convenient size and a face can be ground down on an emery wheel. When we are dealing with metals which can be cut with a saw and filed, a small plate can be prepared. In the case of bars,

rods or rails, much time is saved by using a mechanical saw such as is manufactured by the Millers Falls Manufacturing Company, Mass. With material of a comparatively small size, such as alloys we should prepare, an American hack-saw and a vice are all that is necessary. It is generally advisable to cut a vertical section, because in some cases the structure is not the same at the top and bottom. This is specially the case with alloys whose constituents, the crystals and ground-mass, differ greatly in density; for example, the alloys of tin and antimony. Having obtained a piece of the requisite size, it is now filed comparatively smooth, using a second cut and then a dead smooth file. This is easily performed by holding the file so that the tag rests on the bench and by drawing the section downwards over its surface. When the section consists of some soft material such as lead or tin, care must be taken to keep the file clean, or particles of metal will cling to the file and tend to tear the surface of the section. This tearing effect tends to produce a new crystallization, and unless the metal thus modified is entirely removed during polishing, we obtain, on etching, a structure similar to that produced by rolling or hammering.* This point will be referred to later, when change in the solid is considered.

Having filed the specimen comparatively smooth, it is next rubbed over emery paper or cloth of grade o till all traces of file marks are obliterated. Then it is rubbed over paper or cloth of grade oo till the scratches of the previous paper have disappeared. In some cases it is better to grind on a flat, fine turkey-stone, using either water or oil.

The next part of the process consists of rubbing the specimen over sheets of French emery paper, starting with No. o through oo, ooo to oooo, always stopping as soon as the scratches of the last paper have been removed, and using as little pressure as possible, especially in the case of soft metals or alloys. The emery paper may be attached to a board of suitable size or may be fixed to a disc which

* Campbell : A Note on Crystallization Produced in Solid Metal by Pressure. Physical Soc., London, June, 1900.

can be revolved by a machine. These papers must be kept absolutely free from grit or the specimen will be spoilt. The last two grades may be moistened with oil.

On leaving the last emery paper, the specimen is polished on broadcloth or chamois leather covered with a little well-washed rouge and well moistened with water. Some workers use an intermediate stage, with diamantine powder. This also has to be washed before using. The operation is finished when the last traces of the emery scratches have been removed. This final polishing must not be carried too far or the specimen begins to polish in relief and an uneven surface is produced. A rouge-wheel saves a great deal of time in this operation.

Several polishing machines have been used to save time. Professor Martens has designed one to polish a number of specimens at the same time. It consists of a block to carry the sections, which are pressed on the grinding and polishing discs of a power-driven revolving wheel. At the Royal Mint, London, Prof. Sir Wm. Roberts-Austen uses a series of vertical circular blocks, covered by emery papers of varying grades, and driven by a motor. To polish the specimen, he uses a horizontal rouge-wheel, power-driven and cased in with glass to keep it perfectly free from grits. Stead has designed a small, simple and very efficient machine which can be driven by hand or power. It consists of a horizontal revolving wheel; conical blocks with rings for securing the emery paper, cloth or chamois leather in position; these blocks are simply dropped into the recessed wheel and are carried round by friction. Above is a can to hold either water or the solution to be used; a tap allows the water to drop at a uniform rate upon the center of the polishing block. A shield is used for catching any fluid thrown from the wheel when in motion.

Sauveur has recently devised a machine by which polishing is simplified and the time occupied in the operation greatly shortened. The machine carries four discs revolving in a vertical plane and covered with suitable cloths. The four polishing surfaces are fed automatically from above, and shields are provided to catch any fluid thrown

off from the discs when in revolution. He claims that if the samples (of iron) be delivered to the operator after filing them with a smooth file, fifteen and probably more can be prepared in an hour.

The success in polishing depends to a great extent upon the polishing powders. For ordinary work it is found sufficient to use jewelers' rouge which has been carefully washed free from all large particles. We can go further, however, in the preparation of polishing powders and also of emery powders, and obtain an absolutely accurate classification with regard to size. As Le Chatelier points out in his "Notes on the Technology of Microscopic Metallography,"* this can be performed by the washing method used by Schlöesing for the analysis of kaolins. The carbonate of lime present in tap water causes the formation of lumps of coarse and fine material in the process of levigation. Mr. Schlöesing therefore treats the powders to be classified with water containing some 0.1 per cent. nitric acid, which dissolves the carbonate of lime and other salts which may be present, derived either from the water or from the powder treated. When the mixture has settled, the clear liquid is poured off and is replaced by distilled water. The mixture is well stirred and allowed to settle once more. This is repeated till all acid has been removed, when the settling takes a considerably longer time. A little ammonia is now added to help the suspension of the finest particles. The liquid is drawn off at different intervals by means of a syphon, forming a hook at its extremity to prevent the portions which have settled from being disturbed. The different intervals are: fifteen minutes, leaving all the coarse grains unsuitable for polishing; one hour, leaving a powder suitable to start polishing; four hours, when a powder suitable for polishing hard metals, such as iron, is obtained; twenty-four hours, and eight days, when the finest polishing powders are obtained. The last deposit may be precipitated in a few hours by adding a little acetic acid. In conducting these operations absolute cleanliness is necessary. The

* *Metallographist*, January, 1901.

best way to keep the powders is to mix them with soap so as to form a paste. Powdered castile soap is added to the powders whilst still wet, in the proportion of one part of dry soap to ten parts of wet powder. The mixture is melted in a water-bath, well stirred and allowed to cool. Stirring is kept up till the mass commences to thicken, when it is poured into tin tubes like oil-paints, or into paper ones like grease-paints.

Le Chatelier considers the following to be the best powders to use (given in their order of excellence): Alumina derived from the calcination of ammoniacal alum, commercial flour-emery, oxide of chromium derived from the combustion of bichromate of ammonium, and oxide of iron derived from the calcination in air of iron oxalate.

DEVELOPMENT OF STRUCTURE.

The methods used for the development of the structure are numerous. Etching is the one in most general use. It may be performed with acids, concentrated or dilute, with alkalis or other reagents which attack the specimen. In many cases an electric current has been used with great success. We can also use a combined polishing and etching method, polishing in relief or heat-tinting. The method used depends entirely upon the specimen whose structure we wish to develop. When we wish to follow the changes produced by a certain mechanical or thermal treatment, we must use a constant method for developing the structure; but when we are studying alloys, various reagents should be used for etching; polishing in relief and heat treatment should be employed and the results compared, and in this way the nature of the various constituents can be ascertained.

For carburized irons the combined etching and polishing method of Osmond gives very beautiful results. It consists of rubbing the polished section upon a piece of parchment moistened with an infusion of licorice root, together with a little precipitated calcium sulphate. Instead of these two reagents, a 2 per cent. solution of ammonium nitrate may be used. The results are practically the same.

Le Chatelier recommends the use of commercial tincture of iodine diluted with four times its volume of alcohol. The solution is rubbed over the polished specimen with the finger tips several times until a gray film appears. Care must be taken not to etch the specimen too deeply.

Stead describes a tincture of iodine and iodide of potassium (1.25 grains of each in 100 cubic centimeters alcohol) which he uses. He places the specimen on a plate and allows one drop of the tincture per square centimeter. It is left there until the iodine color has disappeared. Wash in water, then in alcohol; dry by means of hot-air blast. If the etching has not gone far enough, the process is repeated.

For irons which show no free ferrite a dilute solution of nitric acid in alcohol (0.5 per cent.) is often used. The specimen is dipped into the solution and the etching watched by means of a strong lens. When the etching has proceeded far enough the specimen is placed under the tap, then soaked in alcohol and afterwards dried. If this method is used in the case of ferrite, under high powers the ferrite will be seen to have a granular appearance, due to over-etching. For low-power work, however, it answers well.

For rapidly developing the structure of steels under low powers, a 20 per cent. solution of nitric acid is recommended by Osmond. For alloys in general, such as the copper tins, the bearing metals, etc., a dilute solution of nitric acid (1 per cent.) will be found to work well; but for alloys which contain much copper or other metal which is comparatively lightly attacked, such as the gun metals, aluminum bronzes, etc., a more or less strong solution must be used.

Heat tinting, first used by Behrens and Martens, gives very beautiful color effects, which depend upon the formation of films of oxides. The films form at different rates for different constituents. Heycock and Neville have used it with great success, as their papers on the effects of quenching alloys of copper and tin clearly show. Stead has designed a small electrical device for heat tinting, which can be performed by this means upon the stage of the microscope itself. He has obtained some wonderful results

in the case of the alloys of iron and phosphorus.* Heat-tinting does not, as a rule, show up the granular structure, especially that due to differences of orientation; but it is the very best means for showing the different constituents. As it does not remove any metal, the surface always remains flat, and the specimen is less liable to rust than in the case of acids and other reagents.

To preserve specimens from oxidation, etc., the simplest way is to cover the surface with a film of oil. This has the disadvantage, however, that the specimen must be cleaned each time before examination. Le Chatelier recommends that they should be varnished with "Zapon," a solution of gun cotton in amyl acetate. It is transparent and the specimens can be examined under the highest powers.

If we are studying a series of alloys it is often necessary to prepare a large number for fear of overlooking of some slight but important change. A preliminary examination embracing the whole series can be made upon one alloy, as pointed out by Le Chatelier. His results were obtained by superposing the two metals so that they mix only in the vicinity of their contact. A vertical section can be taken through the whole mass and the metals examined alloyed in all proportions from one pure metal to the other. This superposition is very difficult to obtain and often takes quite a while to perform successfully; in fact, in some cases, for example where a combination occurs heavier than the heaviest metal, it is impossible to get correct results. In the case of the brasses and the bronzes it yields excellent results.

When dealing with soft metals and alloys it is extremely difficult to obtain a good surface for microscopical examination, because in the process of polishing, the whole of the metal or alloy is not removed; part of it spreads as a thin film over the surface of the specimen and hides the structure beneath. In the case of slowly cooled specimens I believe Le Chatelier has tried to obtain a good surface by inserting a vertical strip of glass reaching almost to the

**Journal Iron and Steel Institute*, 1900, No. II.

bottom of the crucible, thus dividing the whole into two parts.

In the case of cast metals and alloys, Ewing and Rosenhain* have obtained some excellent results by casting upon plates of glass or of highly polished steel. They found, however, that the glass was very liable to break. If this happens before the specimen is solid, or rather whilst there remains any liquid in contact with the glass, we find part of it running through the cracks produced in the glass, thus spoiling the surface.

Mr. H. J. Hannover† has overcome this difficulty by casting upon mica. He cuts a funnel out of a piece of charcoal, places it on top of a fresh surface of mica, and then pours in his alloy. As this does not always give good results, he casts a small mass of the alloy upon the mica. The alloy thus obtained he places upon another sheet of mica and covers with some potassium cyanide. He then heats it by means of a blowpipe, and when the melting point is reached, places upon it another sheet of mica, previously heated, which he presses down till the alloy is solid. In this way he obtains a very smooth surface on the upper part of the alloy. I have seen this method of casting upon mica in use at the Royal Mint, London, where Roberts-Austen has obtained some very beautiful results.

When casting small ingots of an alloy it is often possible to obtain a clean surface by skimming the metal as it leaves the crucible with a stick of charcoal, retaining any oxides in the pot. On solidification, if this surface be examined, many beautiful and characteristic structures will be met with, and these are often an indication of the internal structure of the alloy.

MICROSCOPIC EXAMINATION.

There are so many papers and books upon the microscope that it will only be necessary here to describe those parts which are more or less peculiar to micro-metallography.

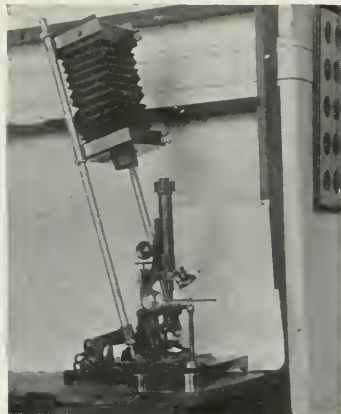
* Royal Society Proc., 1899, p. 85.

† *Bull. de la Soc. d'Encouragement*, August, 1900.

In the first place the stage ought to revolve so that differences in orientation can be observed. It is also very advantageous to have a stage which can be so adjusted that the axis of the microscope is normal to the surface to be examined. This can be effected by means of three leveling screws. Some specimen holders answer this purpose.

The next matter of importance is illumination, which is obtained by means of reflectors. For low-power work, using a 1 inch objective, the Sorby-Beck illuminator or reflector is the best (*Fig. 2, a*). It fits upon the objective. With it oblique and vertical illumination are obtained. To obtain oblique illumination the small mirror, with its face at 45° from the vertical, is turned out of the way. Then the horizontal rays of light are reflected at all angles except vertical upon the surface beneath (provided it is flat and the axis of the microscope is normal to it), and this surface appears dark. Irregularities in the surface will stand out sharply. For vertical illumination the small Sorby mirror is turned into place, and rays of horizontal light falling upon this mirror are reflected vertically upon the surface of the specimen and thence vertically up the tube of the microscope. Horizontal surfaces will therefore appear bright and irregularities will be dark. Vertical illumination for low powers can be simply obtained by a device invented, I believe, by Stead. A small cover-glass is fixed on a glass slide at 45° by wax or cement, and a piece of black cardboard or smoked glass fixed behind it in the vertical. Horizontal rays are reflected just as in the case of the Sorby illuminator; but as they can pass through the cover-glass, this method is rather better for powers below 1 inch, for the Sorby mirror, being attached to the objective, is comparatively far from the specimen.

For high-power work, using higher powers than 1 inch, the Beck illuminator answers very well. In *Fig. 2* the short cylinder contains a small disc of glass; light enters through the circular opening at the side. The illuminator is fixed between the objective and the tube of the micro-

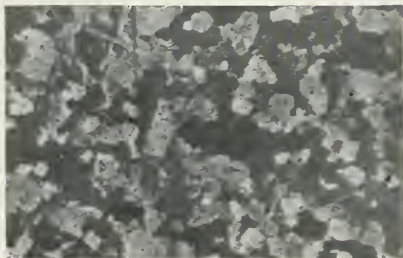


1.



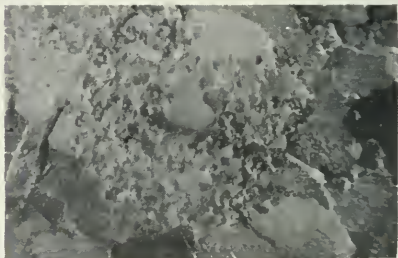
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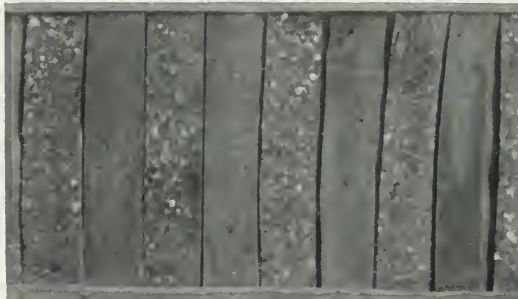
3.

x 33. v.

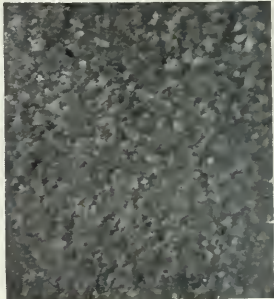


4.

x 33. v.



5.



6.

x 33. o.



7.

x 33. o.



8.

x 33. o.

scope. The disc of glass is set at an angle of 45° , and so light is reflected down the tube, through the objective and onto the specimen. This gives vertical illumination of course. When working with several powers, a multiple nose-piece or a Zeiss objective slide saves much time.

For high powers prism illuminators are also used; these fit between the objective and the microscope tube and work like the Beck. Stead recommends that made by Nachet. He uses the Sorby-Beck with a 1 inch objective, a Nachet prism with the $\frac{1}{4}$ or $\frac{1}{8}$ inch, and the Beck with the $\frac{1}{8}$ inch or $\frac{1}{16}$ inch oil immersion.

For illumination, an incandescent Welsbach light answers well for low powers, and for high powers an arc lamp gives the best results. Bull's eye condensers are generally necessary for all work: A small acetylene lamp has found favor with many workers.

For photographing the object, two methods can be used. In the first case the camera and microscope are vertical, whereas in the second they are horizontal. They both have their advantages. When vertical, it is comparatively an easy matter to place your object; when horizontal, it has to be firmly fixed. But with the vertical method the bellows of the camera must be restricted as to length unless you wish to use a step ladder, or have your dark slide-holder and focussing glass in the room above; whereas, in the horizontal method, the bellows can be of great length and the magnification proportionately increased.

It is really a matter of taste which to use. Stead uses the vertical method, Roberts-Austen the horizontal.

Fig. 1 shows the apparatus used in Professor Howe's laboratory; it is manufactured by the Bausch & Lomb Optical Company and can be used in either position.

The method used by Le Chatelier is fully described in January impression of *Metallographist*, 1901, p. 10.

To any one interested in the details of practical metallography a paper by Stead will prove of great value. It was a lecture delivered to the Cleveland Institution of Engineers in February, 1900. It is reprinted in the *Metallographist* for

July, 1900. Papers by Le Chatelier,* Charpy,† Osmond,‡ Sauveur§ and many others go into the various details so thoroughly that any one can learn with a little patience the art and practice of the science. To those whose time is too fully employed to allow them to read all papers on the subject in the original, Sauveur's journal, the *Metallographist*, will give all that is necessary to follow the subject thoroughly.

THE CRYSTALLINE STRUCTURE OF METALS.

In the *Annales des Mines* for January, 1900, Osmond published a paper on the crystallography of iron, with some very beautiful illustrations. He concludes that iron in its three states crystallizes in the cubic system, but whereas, Gamma-iron crystallizes generally in octohedra, Beta- and Alpha-iron both crystallize out in cubes. In a later paper written in conjunction with G. Cartaud,¶ he confirms his previous results by causing the three allotropic varieties of iron to crystallize out as pure as possible, and at that temperature in which each variety is normally stable, the conditions being such as to allow free development of the crystals, the external forms remaining unaltered by the internal changes which might occur during subsequent cooling. The experiments were conducted in a porcelain tube, internally varnished, placed in a Mermet furnace. A Le Chatelier pyrometer was used to ascertain the temperature, which could be regulated by the gas supply.

Alpha- and Beta-irons were prepared by Pélégot's method,|| which consists in reducing ferrous chloride by hydrogen; whilst Gamma-iron was prepared by the method used by Poumarède,** in which zinc vapor replaces the hydrogen for the reduction of the ferrous chloride. Since the sur-

* *Revue Générale des Sciences*, January, 1897; *Metallographist*, Vol. IV, No. 1.

† *Bull. Soc. d'Enc.*, March, 1897.

‡ *Rapports de la Commission des Méthodes d'Essai*, Vol. II; *Metallographist*, Vol. III.

§ *Metallographist*, Vol. IV, No. 4.

¶ *Annales des Mines*, August, 1900.

|| *Comptes Rendus*, Vol. XIX, p. 670, 1844.

** *Comptes Rendus*, Vol. XXIX, p. 518, 1849.

rounding atmosphere has some influence on the results obtained, some Gamma-iron was prepared by the Pélégot method and some Alpha- and Beta-iron by the Poumarède and the results compared. The paper is full of beautiful photographs and drawings, showing the various forms of crystals obtained. In many cases the crystals shown are identical in form with those prepared at South Kensington by Dr. E. Ball, who distilled galena in a porcelain tube in vacuo.

Ewing and Rosenhain * have developed the crystalline structure of many of the softer metals by casting on glass or polished steel. On examining the surfaces thus prepared various crystalline forms can be clearly seen.

Another way of examining the structure of some metals and of demonstrating their methods of growth is by allowing part of the metal to solidify and then removing the liquid portion. The beautiful crystalline structure of bismuth is brought out in this way. If pure lead be melted in a crucible and allowed to solidify round the outside, by pouring out the whole of the liquid contents a beautiful dendritic structure is revealed. Many beautiful specimens prepared in the laboratory of Dr. Percy are now in the collection at the Royal School of Mines, London.

This dendritic growth of crystals in metals is of very common occurrence. In the case of iron, dendritic crystals often occur in the cavities existing in that portion of the large ingots which solidifies last. Professor Tschernoff has quite a large collection, some of which are about 2 feet long.† On examining the surfaces of small ingots of most metals (and many alloys) we see many good examples. Lead and tin show them. They stand out above the surface of the ingot because they have grown at the surface, and as the metal solidifies the mass contracts more or less, the molten part sinks and they are left standing out in relief. *Fig. 9* shows such dendrites of cadmium, which have the appearance of six-rayed stars, symmetrically arranged about

* Proc. Royal Soc., 1899.

† *Metallographist*, Vol. III, No. 3, p. 199.

a hexagonal axis. From each axis grows a series of parallel branches, making an angle of 60° with that axis, and therefore parallel to the next adjacent axis. Between each pair of axes there is seen the beginning of another axis, thus adding to the hexagonal symmetry.

[*To be concluded.*]

THE TECHNICAL HIGH SCHOOL OF BERLIN.

Technical education in Germany, as is well known, has been developed to a standard of excellence far superior to that of any other of the great powers. The equipment is of the best; the curriculum is most extensive in range; the professors are the best procurable in the various subjects; and every inducement is offered to the pupils to become thoroughly intimate with certain phases of industry. Probably the Berlin Technical High School is the leading institution of this character in Germany, but it is only typical of similar institutions distributed over the German Empire.

At the Berlin school, in the chemical section alone there are six fully qualified professors for the following branches of this science: organic chemistry, inorganic chemistry, chemical technology, metallurgy, electro-chemistry and photo-chemistry.

Further, there are six lecturers for the following branches: chemistry of foods, including analytical and bacteriological methods; agricultural chemical technology (sugar, beer, spirits, etc.); vegetable and animal fats, oils, etc., investigation of mineral oils and naphtha products; designing of chemical works and plants; architectural chemical technology; physical chemistry; thermo-chemistry, etc. The comparatively new chair of photo-chemistry affords instruction in spectral analysis, general photography, photo-chemistry, photographic optics, and the construction of photographic optical instruments.

AMERICAN LOCOMOTIVES IN GERMANY.

An official statement recently published regarding the American locomotives purchased by the Bavarian state railroads declares that so far from being unsatisfactory, as various Continental papers have stated, the American engines have proven themselves in many respects distinctly superior to those manufactured in Germany.

AMERICAN COAL IN GERMANY.

News comes from Germany that American coal is not looked upon with favor by housekeepers and consumers in general. The reason is to be found not in the poor quality of the coal, but in the lack of knowledge of the Germans. The coal is so hard and the stoves so poorly constructed, that the condemnation is not to be wondered at. Despite these obstacles, Germany must now depend largely upon the United States for her supply of anthracite. Great Britain scarcely produces enough for her own consumption.

Mining and Metallurgical Section.

[*Joint meeting of the Section and the American Institute of Mining Engineers, held Wednesday, May 14, 1902, at the Manufacturers' Club, Philadelphia.*]

Steel Rails: Relations between Structure and Durability.

BY ROBERT JOB,
Chemist to the Philadelphia & Reading Railway Company.

An investigation was begun some time ago at the Test Department of the Philadelphia & Reading Railway, to determine qualities in steel rails which resulted in fractures or in relatively rapid wear in service, and to work out the means necessary to reduce these to a minimum.

In order to gain information, arrangements were made to have forwarded to us a section of each rail which fractured in track or which was removed owing to undue rate of wear, together with detailed data regarding it. Such examination and tests as were necessary to establish clearly the cause of failure were then made. A considerable number of rails which gave good results in service have also been tested in the hope of finding fundamental characteristics which might account for the durability or the failure, as the case might be. Also, in our regular rail inspections at the mills, sections representing various methods of manufacture have been taken, and particular attention has been given to investigation of differences between rails which failed under the drop-test and those which passed it successfully.

Results of previous work upon rails had gradually forced the opinion expressed by Sir Lowthian Bell,* that from the results of analysis of rails he could prove and disprove everything that could be said for or against any composition of a rail.

*London meeting American Society of Civil Engineers, 1900. *Trans. A. I. M. E.*, February, 1901. Wm. R. Webster.

We believed then, as we do now, that proper chemical composition is one of the essentials in obtaining the greatest durability in steel rails, but our work had confirmed that of others, which will be referred to below, in proving that physical character and structure have at least an equal influence upon the final outcome. Accordingly, we have not limited ourselves to determining chemical composition, but have tried in each case to ascertain the definite cause of the weakness, whether chemical or physical.

Up to the present time about 200 defective rails have been examined. In some cases complete chemical analyses have been made; in others the loose, coarse-grained fracture or other physical character—such as piping—showed the cause at a glance, and in still others a rather elaborate investigation was necessary to prove the matter to a certainty.

It is evident, of course, that condition and arrangement of track has an important bearing upon durability of rails, and this matter, as we all know, has been worked out exhaustively by Mr. P. H. Dudley.* Our experience, however, indicates that in the large majority of cases with normal track conditions, short life of rails is attributable to the character of the steel, and is seldom found where toughness, strength and solidity exist.

In a general way, the results of analysis in this investigation have merely confirmed the previous opinion, and have proved beyond question that specifying chemical composition alone ensures neither a durable rail nor often a bad rail. We found, however, from the start a marked difference in the structures, and note the following general characteristics in the rails which gave defective service:

(a) Coarse regular granular structure, *Figs. 1 and 8* (50 diameters).

(b) Excess of foreign matter, such as oxides, slag and enclosed gas, *Fig. 2* (reduced 50 per cent.).

Either characteristic resulted in relatively poor service.

On the other hand, in rails of the same general composi-

* *Bulletin International Railway Congress*, xiv, No. 6, June, 1900.

tion giving satisfactory service, we have found (*c*) a generally fine, interlocking, broken up, granular form, with

(*d*) Relative freedom from foreign matter and gas. *Fig. 3*, which will be referred to again, represents a coarse example of this finer structure, and *Fig. 4* shows a characteristic structure of the head, reduced 54 per cent., showing freedom from foreign matter.

Upon comparing the above results with those obtained in our mill inspections we found complete accordance, for the rails of the character *a - b* proved exceedingly fragile under the drop-test of 2,000 pounds falling 20 feet. A section of rail, *Fig. 2*, from center of head, gave an elongation of only 2 per cent. in a 2-inch section, with tensile strength of 118,000 pounds per square inch. The analysis of these rails varied from :

Carbon, .55 to .63 per cent.; phosphorus, .075 to .104 per cent.; manganese, .75 to 1.20 per cent., and sulphur, .034 to .07 per cent.

In contrast with this, rails when of the structure *c - d*, with the above composition, showed a marked toughness under the drop-test, and rail *Fig. 4* stood fourteen blows of the drop without fracture, turning after the first and third blows, and successive odd numbers. The composition was: carbon, .644 per cent.; manganese, 1.09 per cent.; phosphorus, .081 per cent.; sulphur, .076 per cent., and a test piece from a similar rail, center of head, gave an elongation of 13 per cent. in 2 inches, with tensile strength of 132,000 pounds per square inch.

These marked differences were not at all unexpected, for they simply confirm the work of others. Mr. J. E. Stead, for instance, says:* "It is clear that the junctions (of the grains) are a safeguard, and the more junctions there are, the more reliable will the steel be." And again,† "it would seem to follow, then, that the smaller and finer the grain, the safer the structure." This coincides with the researches of Brinell, Sauveur and others.

**Journal Iron and Steel Inst.*, 1898, No. 1, p. 178.

†*Journal Iron and Steel Inst.*, 1898, No. 1, p. 185.

Next, in order to find out how these results tallied with those of practical track service, we made a comparison upon a lot of about fifty rails which fractured in track, each having had a life of less than five years. They came from different points upon our lines, and had approximately the composition stated above. A number of different mills were represented, but all of the rails could be grouped under the head of "coarse-grained," or of "finer grain," and upon figuring the fractures in each class to a basis of equal tonnage during the five years, we found an average of fifteen fractures of the coarse-grained material to one fracture of the relatively finer-grained, and in each case of fracture of the latter, we found that the weakness was due to pipes in the steel—defective cropping. This comparison, of course, applies strictly only to actual fracture, but it is well known that the same conditions which here have produced fracture also contribute to rapid wear in service. Mr. P. H. Dudley states: * "As I have already observed, the most serviceable rails have a fine structure and small mineral aggregates, though in many cases the so-called chemical composition is identical."

In our own work upon bearing metals† we have invariably found these conditions true, namely, coarse grain and presence of foreign matter result in relatively rapid wear in service.

Turning now to the influence of mill methods upon the size of grain.

During the past ten years marked progress has been made in knowledge regarding the metallurgy of steel, and, thanks to the work of efficient investigators, the general relations between structure of steel and its physical properties are so well proven that cause and effect in many conditions of mill practice have become matters of definite certainty. The cause of coarse granular form is clearly shown in Prof. Sauveur's valuable papers of 1893 before the American Institute of Mining Engineers,‡ and of

* *Trans. A. I. M. E.*, 1893, xxiii, p. 651.

† *Jour. Franklin Inst.*, 1900, cxlix, p. 449.

‡ *Trans. A. I. M. E.*, xxii, p. 547.

1899 before the Iron and Steel Institute.* Proposition V of the latter states: "The higher the temperature above W from which the steel is allowed to cool undisturbedly the larger the grains," and Proposition VI, "The slower the cooling from a temperature above W the larger the grains." In other words, stopping thorough working of the steel while materially above the recalescent point, and allowing to cool slowly, can result only in coarse granular structure, and such structure, other things being the same, has been proved by Professor Sauveur,† Professor Martens,‡ Mr. C. H. Ridsdale,§ Mr. R. G. Morse,¶ Dr. Sargent,|| and others, to lower elongation and reduction of area, and to lessen the general toughness of the steel. Professor Roberts-Austen, also, in summing up the results of the important investigation made by the British Government after the St. Neots disaster, concerning loss of strength in rails, states: "The character of the grain, therefore, affords valuable evidence as to whether the rail has been rolled at a suitable temperature. . . . The relative amounts of the pearlite and ferrite, as well as the relative dimensions of the respective granules, afford very valuable indications as to the qualities of the rail and its probable durability."**

It will thus be seen that the unsatisfactory results which our service tests show with this coarse granular structure are merely the natural accompaniments of such character, and the entire investigation proves clearly the immense practical advantage in the betterment of quality which is being derived from the researches of metallurgists and metallographists, especially during the past decade.

The mills have not been slow to recognize the need of

* *Jour. Iron and Steel Inst.*, 1899, No. 2, p. 195. *Metallographist*, ii, p. 266.

† *Trans. A. I. M. E.*, 1893, xxii, p. 556.

‡ *Mittheilungen aus den Koniglichen technischen Versuchsanstalten*, xiv, 1896, p. 89.

§ *Jour. Iron and Steel Inst.*, 1898, No. 1, p. 234; 1899, No. 2, p. 128; 1901, No. 2, p. 75.

¶ *Trans. A. I. M. E.*, 1899, xxix, p. 731.

|| *Trans. A. I. M. E.*, Richmond meeting, Feb., 1901.

** English Govt. Report on "Loss of Strength in Steel Rails," 1900, p. 58.

fine-grained structure in the heavier sections, and during recent years great efforts have been made to effect the change, and much progress has followed. At first, attention was directed merely to the finishing temperature; that is, the temperature at which the rail came through the last pass, without particular regard to the initial temperature of the ingot or bloom. In fact, high initial temperatures tended to prevail out of deference to the rolls, especially where these were light, or where the power was limited, and under such conditions it became necessary to hold the rails before running through the last passes, in order to finish at the desired temperature. The result of this procedure, as pointed out by Mr. S. S. Martin recently,* was to produce a fine granular form to the depth to which the working of the steel extended during these last passes, or to a depth of from $\frac{1}{8}$ to $\frac{1}{4}$ inch below the surface of the head.

Our own studies had proved the correctness of this statement, and further showed that the size of grain at center of head was but little affected by such treatment, as shown in *Fig. 5* (50 diameters). A surface toughening resulted, which would be of temporary benefit only, and could hardly from its nature cause any very decided increase in durability in service. The character needed is not a fine-and-coarse irregular structure, but one fairly fine even at the center of head, and practically amorphous at the surface; just such a structure, in fact, as we find in the rails of lighter sections rolled before the heavier sections came into use. *Fig. 6* (50 diameters) represents the structure at center of head of a 67-pound rail which was rolled and laid in 1864, and which withstood thirty-four years' heavy traffic, and since then has been in use in side track. The analysis is:

Carbon	'33 per cent.
Phosphorus	'039 " "
Manganese	'390 " "
Sulphur	'030 " "
Silicon	'070 " "

Fig. 7 (reduced 64 per cent.) represents the appearance of this rail in 1898, etched, and shows that it had evidently been

* *Iron Age*, Dec. 26, 1901.

greatly worn from its original section, and contained a pipe in the web. The metal, however, has not "flowed over" upon the side of head, although the steel is comparatively soft. In explanation, however, it is to be noted that the head is almost free from foreign matter, and that the structure even at center of head is exceedingly fine.

"Flowing over" has been found by us to be practically independent of the composition, and caused generally by unwelded seams due to presence of foreign matter and gas in the steel. In 1890 Dr. C. B. Dudley stated* that his studies of such rails "would seem to indicate that disintegration or crushing of steel is largely a resultant of lack of soundness in the ingot, and is more mechanical than chemical, except in so far as chemistry may be responsible for the soundness of the ingot." In some cases, however, we have found almost complete freedom from unsoundness, but in each such instance a coarse granular structure was present. Mr. P. H. Dudley also states:† "The mineral aggregates are large and friable, and the surface of the rail breaks down more than $\frac{1}{32}$ of an inch in depth, readily flowing under wheel pressures." Thus, it seems clearly established that such condition may arise from marked weakness due to any cause, whether unsoundness of the metal; weak, coarse structure, or even such composition or form that the rail is unable to support the load and becomes flattened.

In the case of the 67-pound rail, *Figs. 6 and 7*, which gave excellent service, the composition is exceptionally free from defects. It is, however, a matter of common experience everywhere that the composition of these old rails of light sections is exceedingly irregular. As Captain Robert W. Hunt expressed it last year before the American Institute of Mining Engineers,‡ "they were high in carbon and low in carbon; high in manganese and low in that element; high in phosphorus and higher in phosphorus; but they all gave good service." One such rail taken from our tracks contained .160 per cent. phosphorus with .44 per cent. carbon,

* *Trans. A. I. M. E.*, 1890, xix, p. 893.

† *Trans. A. I. M. E.*, 1893, xxiii, p. 650.

‡ *Trans. A. I. M. E.*, Richmond meeting, Feb., 1901.

but still had given long service. The one characteristic common to all of these rails is that of fine granular structure; in fact, it was necessitated by the conditions under which they were rolled, for the steel was thoroughly worked well down toward the critical point.

In order to note the exact influence of structure upon quality, we took at random from a heat which passed the drop-test a rail having the following composition:

Carbon56 per cent.
Phosphorus102 " "
Manganese	1.08 " "
Sulphur056 " "
Silicon147 " "

turned down a section at center of head and obtained the following results:

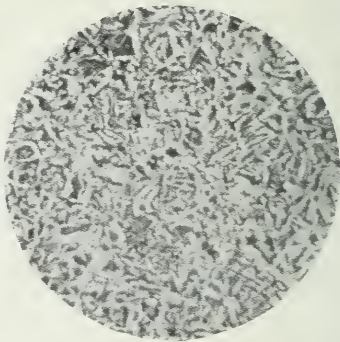
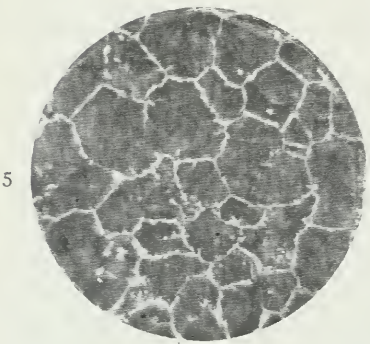
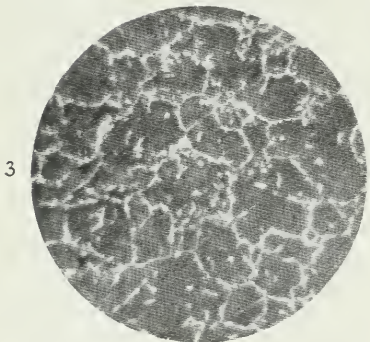
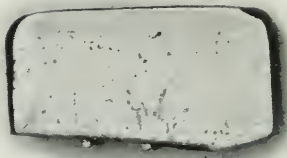
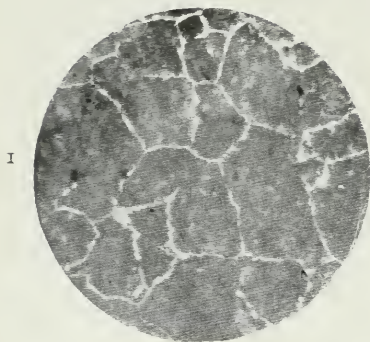
Tensile strength	128,400 lbs. per sq. in.
Elongation in 2 in.	8½ per cent.
Reduction of area	3½ " "

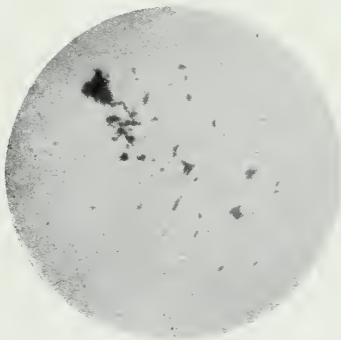
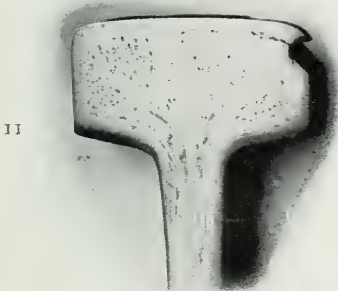
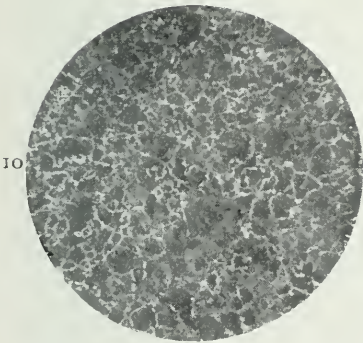
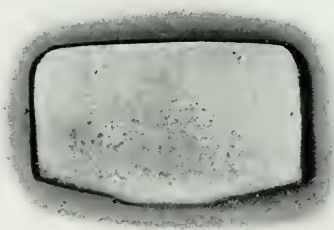
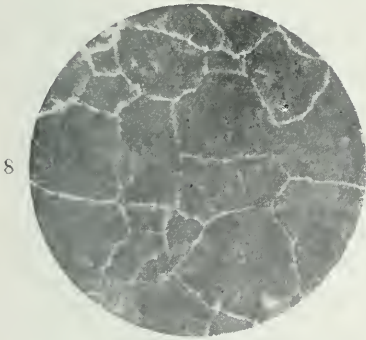
The structure (50 diameters) at center of head is shown in *Fig. 8*, and the etched head (reduced 50 per cent.) in *Fig. 9*. The former is very coarse, but the latter is tolerably free from foreign matter.

An adjoining portion of the same rail was then reheated to a cherry red, and let cool at once in the air. A test section was then turned from the center of head, having a structure (50 diameters) represented in *Fig. 10*, and gave the following results:

Tensile strength	129,500 lbs. per sq. in.
Elongation in 2 in.	12 per cent.
Reduction of area	10.1 " "

It is thus seen that the change shown in the structure has caused an increase of strength, an increase of nearly fifty per cent. in elongation, and an increase of nearly three-fold in reduction of area, fully accounting for the marked difference observed in service between the coarser and the finer structures, respectively. As Mr. William R. Webster stated at the Paris Congress of the International Associa-





tion for Testing Materials, in 1900:† “The matter of vital importance is to work steel in such manner that it is not put in service with this coarse grain.”

In the foregoing we have seen that coarse granular structure seriously weakens steel, and that brittleness under the drop-test is found when in addition the metal is “burned” or contains an excess of foreign matter. The result of a large number of tests further proves that fracture under the drop-test seldom occurs if the steel is homogeneous and free from unsoundness. In other words, mere ability of rails of this composition to withstand the drop-test is no guarantee of fine granular structure, and consequently other tests of quality are essential to necessitate durability. *Figs. 1 and 8* represent rails of coarse granular structure which passed the drop-test with good deflection, but such rails do not give satisfactory service.

The foreign matter and gas which produced brittleness was generally found in small cavities or lines scattered throughout the section, but especially prominent within $\frac{1}{2}$ inch from the surface around the head, and caused a series of unwelded seams—elements of weakness. The appearance was usually similar to that of *Fig. 2*. Rails which did not fracture under the drop-test at the same rolling were found comparatively free from this enclosed matter around the outer portion of the head, though in some cases a considerable proportion was found nearer the web. Still, the solid band of homogeneous material around the outside of the head gave sufficient toughness to the rail to enable it to resist the force of the drop. It is of interest, however, to note that an excessive proportion of foreign matter and gas in rails may not cause failure under the drop-test in cases where the grain is comparatively fine, since the strength incident to such structure may offset the weakness caused by the unsoundness. A typical case came under our observation not long ago. A lot of 90-pound rails had been rolled, and had passed the drop-test without a single failure, and the average structure was somewhat finer than that represented

* *Engineering*, August 10, 1900, p. 193.

in *Fig. 3*. After being in tracks for a few months a number of the rails began to flow over and break down under the heavy traffic to such an extent that replacement became necessary. Upon inspecting the track we found that some of the rails from the same rolling were in good condition, showing little wear, while others next to them were badly broken down, often along the entire length. The defective rails were not confined to any one heat, but were scattered throughout the rolling. Sometimes the outside edge of a rail was broken down, and sometimes the inside edge. Some in a given heat were showing good service, while one or more from the same heat were defective. Eighty-pound rails of practically the same composition had previously been in this track and had given good service, and had not been broken down by the same traffic.

In order to get at the cause of the difficulty, sections of some of the defective rails were obtained, and showed the following average composition:

Carbon544 per cent.
Manganese	1.005 " "
Phosphorus078 " "
Sulphur090 " "
Silicon120 " "

There was nothing abnormal in this, and many rails of essentially the same composition have given good results under heavy traffic conditions.

We next investigated the structure of the steel. *Fig. 12* represents the general character of the fracture magnified to $1\frac{1}{2}$ diameters, and is a longitudinal section down through the head of the rail about $\frac{1}{2}$ inch from the center line. The striations which appear are unwelded seams which break up the continuity of the steel and produce planes of weakness. In order to learn the extent of these defects, we polished off a full section of the rail and etched lightly with iodine, finding that the entire surface of the section was covered with lines of unwelded seams, as represented in *Fig. 11* (reduced 52 per cent.). Microscopic examination showed that the steel contained a large number of particles of foreign matter—*Fig. 13* (x 50 diameters)

—and that some seams were coated with blue and brownish films, evidence that the steel had been burned,* and fully accounting for the failure to weld. *Fig. 3* gives a section from center of head, and proves that the rail was worked and finished at a moderately low temperature, and that owing to the consequent fairly fine structure the rails withstood the drop-test in spite of the weakness due to defective manufacture. When laid in track, the weight of the rolling stock caused the unwelded seams to slip apart at the portions where the greatest strain came, thus resulting in the breaking down of the rails. The upper right-hand corner of *Fig. 11* shows where a sliver $\frac{1}{2}$ inch thick was forced out of the side of the head along one of the unwelded seams for a distance of several feet, and the crack along the seam extended nearly to the top of the head.

This instance proved conclusively that reliance could not be placed upon the drop-test to ensure homogeneous, solid steel, and it is generally well known that rails of laminated steel may give even a better test under the drop than if composed of solid metal of the same composition.

The above results clearly verify the statement of Mr. P. H. Dudley † that solidity and continuity are quite as important as a good microstructure.

As to the origin of foreign matter in steel, it is evident that it must be due to defective mill practice either in the manufacture of the steel, including teeming and settling; in burning of steel in soaking pits—or in blooming furnaces, if the latter are used,—or in cropping blooms or rails; in any event, it is an unquestioned proof of defective mill practice, and is easily avoided if so desired.

In order to ensure the most durable rail of a given composition, our service results, as shown above, indicate that there must be—

- (1) Freedom from brittleness.
- (2) Absence of unsoundness.
- (3) Fine granular structure.

* J. E. Stead: *Journal Iron and Steel Institute*, 1898, No. 1, p. 183.

† *Trans. A. I. M. E.*, 1893, xxiii, p. 652.

(1) Brittle rails are eliminated by the drop-test of 2,000 pounds falling 20 feet upon a rail-butt from the top of the ingot, one rail from each heat being tested, or, in case of fracture, two more being taken from the tops of other ingots of the same heat; fracture of two out of the three causing rejection of all rails in the heat.

(2) Absence of unsoundness is best ensured by careful inspection throughout the manufacture, and by specifying a definite proportion of cropping.

(3) Fine granular structure is necessitated by specifying, under definite conditions, the shrinkage of the rail after leaving hot saws—an idea suggested by Mr. Wm. R. Webster.*

A shrinkage limit is in operation in most of the mills to-day, but it must be borne in mind, as pointed out by Mr. Martin in the paper above referred to,† that specifying merely the distance between hot saws does not compel presence of fine grain clear to center of head. Such structure will not result unless the reduction in the passes after the holding is sufficient to work the steel thoroughly to the center.

What is needed is a moderately low initial temperature, sufficient work to render the steel solid, the speed of train and extent of reduction being such that with rapid rolling—without undue holding before or in the last passes, and without artificial cooling subsequently—the distance between hot saws shall not exceed a specified amount.

Under the above conditions, with a given composition, the extent of shrinkage of the rail after leaving hot saws may be made a definite guarantee of size of grain in sections of a given weight, and if the limit is placed at $5\frac{1}{2}$ inches for a 30-foot length of a 90-pound rail, coarse grain even at center of head is practically impossible.

It is, of course, obvious that mere fine grain does not render certain freedom from brittleness, as, for instance, in the case of the St. Neots rail above referred to,‡ where the steel

* *Engineering*, August 10, 1903, p. 192.

† *Iron Age*, Dec. 26, 1901.

‡ Page 21, above

was fairly fine-grained, but was fragile owing, it is said, to presence of martensite due to rapid cooling from a high temperature. Such composition was, however, evidently caused by a very exceptional accident in mill practice, and is carefully guarded against under normal conditions.

In working toward the most efficient practice in rail rolling, valuable aid has been given during the past few years by Committee No. 1 of the American Section of the International Association for Testing Materials, and Mr. Wm. R. Webster, the chairman, deservedly receives great credit for his efforts in bringing together the various conflicting interests, and in formulating proposed standard specifications of various materials of construction. The specifications for steel rails in particular have aroused wide discussion. In its present form we regard it as tentative, since it merely specifies the quality which, since the introduction of the heavier sections, has everywhere been found rapid wearing and unsatisfactory. It does not ensure durable material, and it does not represent the best American practice. It will, however, serve as a basis to which the necessary additions or modifications can be made, and also its effect in provoking discussion will be of assistance. If so drawn as to represent the best American practice, it would benefit the railroads as a class, and would undoubtedly be of great commercial value to the mills as an influence upon foreign orders, and would go far toward proving that many rail failures and cases of brittleness attributed abroad to chemical composition have been simply results there of defective mill practice which would not be found under the given best American practice. As an instance, we may cite the statement of Mr. C. P. Sandberg before the International Railway Congress in 1901,* that he made some experimental tests with rails containing up to .60 per cent. carbon, and met with complete failure. The rails were brittle, and broke under a drop-test of 1 ton falling 10 feet. The carbon ranged from .56 per cent. to .62 per cent. In

* *Bulletin International Railway Congress*, English Ed., xv, p. 1647, July, 1901. Also *four. Iron and Steel Inst.*, 1898, No. 2, p. 78.

contrast with this we have the regular practice of our American mills, where, as shown above, failure under the drop-test of 2,000 pounds falling 20 feet seldom occurs, even with carbon considerably beyond the .60 per cent. limit, provided proper care is exercised in manufacture.

The specifications proposed to the American Railway Engineering and Maintenance of Way Association* are an improvement over those of the International Association in inserting a shrinkage clause, but the wording of the latter is open to the objection cited by Mr. Martin,† and would ensure merely fine-grained material upon the immediate outer surface of the rail.

Every successful specification is of necessity based directly upon the teachings of actual service. In order, then, to aid the mills in working out the most efficient standard practice, it is greatly to the interest of every consumer to make known the practical service values of the various materials. Our object in entering upon this investigation has been, naturally, to secure the greatest degree of safety and durability in the tracks of the Reading Railway, but we have brought the results to your attention in the hope that a full and free discussion of facts may be of general benefit in tending toward the production of uniformly durable material.

In conclusion, I wish to thank my assistants for the analytical and inspection work carried on in connection with this investigation.

READING, PA., May 15, 1902.

EXPLANATION OF PLATES.

Fig. 1.—x 50 diameters. Center of head. Coarse open grain which wears rapidly in service.

Fig. 2.—(Reduced 50 per cent.) Foreign matter which causes brittleness.

Fig. 3.—x 50 diameters. Finer granular form which gives much better service than *Fig. 1.*

Fig. 4.—(Reduced 54 per cent.) Freedom from foreign matter.

Fig. 5.—x 50 diameters. Center of head. Rail held before last two passes.

* *Amer. Railway Engineering and Maintenance of Way Asso. Bulletin*, 22, March, 1902.

† Above, pages 22 and 28.

Fig. 6.—x 50 diameters. Center of head. Very durable and slow wearing. Thirty-four years of hard service.

Fig. 7.—(Reduced 64 per cent.) Homogeneous head. Rail, *Fig. 6*, after thirty-four years' service.

Fig. 8.—x 50 diameters. Rapid-wearing rail, stood drop-test.

Fig. 9.—Reduced 50 per cent.) Foreign matter in *Fig. 8*.

Fig. 10.—x 50 diameters. Center of head. *Fig. 8* re-heated.

Fig. 11.—(Reduced 52 per cent.) Mashed down in track after six months' wear.

Fig. 12.—x $1\frac{1}{2}$ diameters. Fracture of *Fig. 11*, showing unwelded seams.

Fig. 13.—x 50 diameters. Oxide spots in *Figs. 11* and *12*, preventing welding.

[To be concluded.]

STATISTICAL REVIEW OF THE ELECTRO-METALLURGICAL INDUSTRIES OF GERMANY; DEPOSITION OF ZINC.

There are four sodium plants; two use the Castner process; two the Rathenau and Suter process; one plant makes sodium for the production of cyanides and sodium peroxide, caustic soda being the raw material. There are seven copper works; the total copper production of Germany has increased from 24,700 to 32,000 tons in the last ten years. Some interesting notes are given concerning the Papenburg works; while it has been generally supposed that the Hoepfner copper process is there in extensive use, it is said that only a small quantity of copper is produced there at present, and that probably the production of copper at that plant will be given up, "because copper-nickel matte is not available;" the original Hoepfner process, as it has been used in the Weidenau trial plant, is described in detail; the process is said to have been modified later. The Elmore process, in use at Schladerm for making copper tubes, is said to have reached remarkable perfection. At a Hamburg refinery about 3,000 kilograms of fine gold are produced yearly by the Wohlwill process, the anodes being of raw gold, 980 fine, with impurities of platinum and silver; from the sludge about 12 to 15 kilograms of platinum are obtained. Besides this, still greater quantities of Transvaal gold, down to 850 fine, are electrolytically refined. The electrolytic zinc industry is still in its infancy; in most works the operation has ceased. Some interesting remarks are made on the electrolytic deposition of zinc from solutions. The deposition of pure solid zinc is impossible, if the solution contains many impurities. Zinc is more electropositive than hydrogen and can be obtained from neutral or slightly acid solutions only for the reason that a higher E.M.F. is required to make a hydrogen ion give off its charge at a zinc electrode than at an electrode of most other metals (which evidently means, on account of the "Ueberspannung"). If the solution contains impurities of metals which are more electronegative, these are preferably deposited with the result that the cathode is then no longer pure zinc, but is mixed with other metals by which a hydrogen ion gives off its charge more easily than a zinc ion. The most dangerous impurity is iron. In reference to the troubles in the analytical examination of zinc by electrolysis

if iron is in the solution ; as long as there are much more zinc ions than iron ions, zinc is deposited ; but when the ratio of the number of iron ions to that of zinc ions reaches a certain value, iron is deposited together with the zinc ; the cathode then contains iron, and at this iron hydrogen ions can give off their charges more easily than zinc ions ; zinc is dissolved with vivid development of hydrogen and disappears from the platinum pan. This is brought into connection with the influence of current density upon the form of the zinc deposit. When a pure zinc salt solution is electrolyzed with a pure zinc cathode, zinc is deposited and hydrogen appears only at very high current densities. If, however, the solution contains iron ions, iron is deposited preferably, and at the ion deposit, thus formed, hydrogen gives off its charge preferably at low current density, and hydrogen together with zinc at medium current densities. If, however, the current density is great enough, the small iron particles on the cathode are quickly covered with zinc, so that the cathode becomes again pure zinc and no hydrogen is given off ; only at very high current densities are zinc and hydrogen again deposited simultaneously. This may be the reason why from pure solutions a good zinc deposit is obtained at low and medium current density, and spongy zinc at very high current densities ; on the other hand, from impure solutions as they exist in practice, spongy zinc is obtained at low and very high current densities, and a good zinc deposit at medium current densities.—*Zeit. f. Elektrochemie*, through the *Electrical World*.

MICA SPRINGS.

The *American Machinist*, of recent date, says : " Mr. W. C. Leland, a machinist of Brooklyn, referring to our inquiry some time ago for a spring made of a substance which would not be affected by heat, sends us some pieces of mica arranged to act as a flat spring, and he says that a mica spring continues to act as a spring when exposed to very high temperatures. A specimen he sends us acts as a spring when held in a gas flame and continues to so act for a considerable time—at least as long as our patience has held out to test it. Of course, as many layers of mica may be superposed as is necessary to get the desired thickness, and for experimental purposes at least we would imagine that such a spring may be quite useful."

HIGHER SPEEDS ON RAILWAYS.

Efforts to attain higher speeds upon railways, both steam and electric, have not yet met with much success; the latest electrical railway, that of the Berlin-Zossen line in Germany, having failed to reach the hopes of its projectors. It was planned to run trains at a velocity of 125 miles per hour, but it has been abandoned when only 100 miles per hour was reached for a short distance. The facts are that there are no precedents for the task that was undertaken in the Berlin-Zossen enterprise, and all sorts of obstacles were encountered at the start, the principal one being that, even in its brief existence, it was found impossible to maintain a safe track, and this upon a practically straight line. Steam railways, with the most powerful locomotives of modern build and only two-car trains, cannot get above seventy miles an hour for runs under 100 miles.

Haupt's Reaction Breakwater.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Prof. Lewis M. Haupt. Sub-Committee: Ambrose E. Lehman, Chairman; John Haug, Louis E. Levy.*]

HALL OF THE FRANKLIN INSTITUTE,

[No. 2163.] PHILADELPHIA, December 5, 1900.

The Franklin Institute of the State of Pennsylvania for the promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of Haupt's Reaction Breakwater, reports as follows:

This invention consists of a method and means of application whereby channels opening in tidal waters may be made practically navigable for vessels of deep draft, and requisite depth maintained by the operation of natural forces alone, and without continued dredging.

The inventor's work includes an extended investigation of the natural laws controlling the formation of harbor-bars, sand spits and other physical features composed of littoral drift on alluvial coasts, and a determination of the data relating to these subjects.

The invention is submitted to your committee in the developed form which it has taken in the course of experience since its first introduction by the inventor, thirteen years ago. At various stages during this interval, the subject has received the consideration of a number of scientific bodies and of eminent maritime engineers, and the theories of the inventor, approved in these discussions, have been further elucidated by the official surveys and charts of the United States Coast and Geodetic Survey, and of the United States Engineers in charge of harbor improvements.

In the year 1887, the American Philosophical Society, after a careful investigation of Professor Haupt's Reaction Breakwater System, through a committee of its members, conferred upon him the Magellanic premium and gold medal for his masterly presentation of this subject in a paper

under the title, "The Physical Phenomena of Harbor Entrances; their Causes and Remedies and Defects of Present Methods of Improvement." This paper was published in the proceedings of that society in 1888, and the report of the committee is on file in its archives.

For three models illustrative of Aransas Pass, Texas, and its conditions as a port of entry, with plans for its improvement, exhibited at the National Export Exposition of 1899, Professor Haupt was awarded the highest premium, a silver medal and diploma. At the Paris Exposition of 1900 a similar exhibit, consisting of models and plans for the removal of ocean-bars and alluvial obstructions in the paths of navigation, and for the improvement of the South West Pass of the Mississippi River, by a reaction jetty or breakwater, was awarded a gold medal and diploma. The members of the jury of awards were men most prominent in their profession and well qualified to judge matters of this nature.

In October, 1899, Professor Haupt's methods and inventions were the subject of earnest and exhaustive discussion in the American Society of Civil Engineers by some of its members of large experience as maritime engineers. On this occasion they bore a very searching analysis and received a favorable verdict based upon facts proceeding from actual tests of the theory of the Reaction Breakwater or single-curved jetty.

Heretofore it has been extensively the practice to construct jetties or breakwaters in pairs, so placed that the ebb currents thus confined in a constricted passage may cause an increased scour, and when in any case the full results are not attained, spur jetties projecting from the main jetties towards the center of the channel are added to increase the contraction.

These methods do not as a rule serve their purpose to a satisfactory extent, and in many instances constant dredging is required to keep the channel open. To the cost of construction of the two jetties must therefore be added that of maintaining the required depth of water by auxiliary means.

The purpose of the applicant has been to simplify and render more effective and economical the methods of securing and maintaining navigable channels over or through ocean bars. Few men with the ability to work out these problems would have had the intrepidity to undertake so formidable a task, involving as it did long periods of investigation and study in field and office, over a wide range of physical phenomena, most obscure and difficult of access. That his theoretical conclusions have been practically verified is exemplified at Aransas Pass, Texas. Here the natural conditions and forces were carefully studied and most effectively applied by the use of a single detached curved breakwater designed on this system, although the structure is not yet fully complete to the extent of the original plans. This example consists of a single jetty in the form of a compound and reversed curve placed to "windward" of the navigable channel and generally in line with the natural trend of the currents. An open space is left between the shore and the head of the jetty to admit the flood tide freely. This opening changes the conditions of equilibrium between the flood and ebb movements in such a manner as to cause a larger volume of the ebb currents to pass over a contracted section of the bar, and thus scour out the channel. Such, briefly described, is the Reaction Breakwater at Aransas Pass. The depth of water over the bar has been materially and progressively increased by the utilization of the natural forces only and is maintained without interruption.

The increasing size and draft of vessels call for depths of channels of not less than 35 feet, and experience has abundantly proven that the methods in most general use are inadequate to create or maintain these necessary channel dimensions without great expense.

In applying the general principle involved in the Haupt Reaction Breakwater, the conditions to be fulfilled may be briefly summarized in the order of their relative importance, as follows:

(1) To arrest the littoral drift before it reaches the channel.

(2) In sea-coast inlets, to permit free ingress of the flood tide by placing the work so as to interfere as little as possible with its entrance.

(3) To so adjust the plant that the spreading of the out-flowing waters over the outer area may be confined to a single channel across that section of the bar where the external forces are weakest.

(4) By thus changing the conditions of equilibrium the efflux currents may be made to produce a local excess of energy in favor of the ebb movement.

(5) The effect of the curved breakwater is to produce a continuous reaction entirely across the bar, thus causing counter currents which will erode the bottom of the channel and convey the silt to the convex side of the entrance.

(6) By this means the extension of the bar seaward is prevented and a counterpart of the jetty is produced on the opposite bank of the channel without expense, this counter-spit automatically adjusting itself to the local requirements.

(7) As the construction of one breakwater is thus required, instead of two, and as its length is less than half of that of the parallel jetty system, the expense of the work will be proportionately less.

(8) The desired result is also secured in much less time than by former methods, because of the more rapid erosion of the channel. This process is furthered by the utilization of the forces of gravity as well as of impact and momentum to cut away the bar, thus reducing the necessity of dredging and possibly dispensing with it altogether.

(9) It naturally follows that a channel produced by utilizing the forces of the current will be, in a large measure, self-sustaining so long as the conditions that cause it are effective.

(10) As the channel is thus formed by the natural forces and currents and therefore adapted to their conditions, no injury can result to the stream, pass or inlet from excessive contraction, as has sometimes happened from parallel and spur jetties.

For further and more minute detail concerning the features and merits of the Haupt Reaction Breakwater

System, reference is directed to the letters-patent (No. 380,569, of April 3, 1888) and to the publications of the American Philosophical Society; the American Society of Civil Engineers; the *Journal of the Franklin Institute*; the report of the judges of the National Export Exposition, and the official reports of the United States Coast and Geodetic Survey and of the United States engineers in charge of harbor improvements.

In recognition of the scientific research and practical efforts which have culminated in the invention and demonstration of the Reaction Breakwater, and of the economies to commerce resulting therefrom, the Franklin Institute bestows the highest award within its gift, the Elliott Cresson Medal, upon Prof. Lewis M. Haupt, the inventor of this system of harbor improvement.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, January 2, 1901.

Attest: WM. H. WAHL, *Secretary*.

APPENDIX.

REPORT OF THE COMMITTEE OF JUDGES OF THE NATIONAL EXPORT
EXPOSITION, CLASS 40, ON THE SUBJECT OF THE CLAIM OF
PROF. LEWIS M. HAUPT FOR HARBOR IMPROVEMENTS
BY MEANS OF A REACTION BREAKWATER.

Directly opposed to the popular belief that everything is formed by nature for the express needs of man, investigation finds one of its most flagrant contradictions in the fact that, although man is commercial by instinct and education, harbors may be absent over long stretches of coast, or that they may be so poor as to make the intervention of man necessary for their improvement and maintenance. Maritime engineers, however, fully recognize these to be facts, and are sedulously engaged, the world over, in seeking to rectify, or at least to ameliorate, defects in conditions which they cannot create.

Of all opportunities offered in this direction, none are so great as those involved in the betterment of channels passing through alluvial shores directly to the sea. As to those channels, one should suppose that, from careful study, it would be clearly seen by all, what nature, through the constant exercise of her functions, points out as the best methods by which her forces can be directed towards the modification of what she has not, for man's special needs, accomplished at first hand

as the best attainable results. For the plainest possible instance of the natural conditions which point the way towards the betterment of such alluvial channels, we cannot have a better illustration than that afforded by the shores of the United States from Sandy Hook to the Rio Grande and beyond. Along these is to be seen a continental belt of narrow islands, once shoals, afterwards spits of sand, and now, with the breaks between them, called inlets, a nearly continuous breakwater against the encroachment of the sea. Back of this long line of outworks of the continental shore, therefore, lie bays of greater or less area, drained by these inlets.

The nearly continuous breakwater formed by these narrow islands would be actually continuous but for the fact that the bays, as well as the sea, perform a function in the details of this sort of construction. They and the sea together determine the particular points where the inlets draining bays shall be. Through their instrumentality, in conjunction with that of the sea, are moulded all the details relating to the trend and general character of all fringed coasts of this kind. By the sea is to be understood all that relates to it as the all-embracing factor in one set of effects produced, just as by the land is to be understood the other factor, whose all-embracing agency contributes by another set of effects to the resultant. In a word, we have, in the formation of such alluvial basins and inlets as are here under consideration, results from which the character and amount of energy of nature at each point is clearly recognizable. That is, one can, through careful study of the physical actions involved in the problem, not only distinguish their respective operative causes, although compounded, concerned in the production of the final physical event. And it is obvious that, if man is able by study to recognize clearly the elements of causation in this case, to form a correct diagnosis of it, he should be able artificially to better the physical conditions, by which they are represented, through modes of working hand in hand with nature, as elsewhere in mechanics, for the transmission to the best advantage of her energy.

Any main coast is chiefly determined geologically by vertical forces, and in a case of the kind under consideration, is topographically modified by the influence of the land and of the sea, through its winds and currents and waves acting upon material light enough to be held in suspension during longer or shorter periods of transportation. Notwithstanding that the rise and fall of the tide on the Florida Reef is between 1 and 2 feet, and, therefore, any possible current superinduced by it in the narrowest inlet between Keys is necessarily far from swift, the waters of the inlet on each side of Key Biscayne may sometimes be seen to change within a few minutes from crystal clearness to milky whiteness, from the inflow of current there, due to the rise of the tide generating current passing through the inlets and transporting

minute particles of disintegrated coral to add to the elevated marl-beds of Biscayne Bay. What is so evident to the eye in this case, on account of the whiteness of material borne in suspension in the water, occurs also in other cases where silicious sand is the burden of the water; for where currents are stronger than here, they scour muddy, sandy, and other bottoms, and the sides of the channels, with strength proportional to their velocity and volume—to their momentum. The most careless observer of sandy beaches takes notice that the waves, beating on the shore with violence, churn up particles of sand and other detritus, and that these are borne off by currents for longer or shorter distances, and that even the tiny ripple disturbs some sandy shores, and leaves its trace in sand transported and deposited in serrated lines for distances representing the force of the impact of the water, or with the current sent for greater distances in long smooth stretches far along the shore.

The most primitive of all methods that can be conceived of for establishing an effectual channel for efflux and influx of water along such coasts as these we are considering is to build two parallel, or approximately parallel, jetties passing outward from an inlet to the sea, regardless of the prevalent winds and currents of the region, and periodically to dredge out the sediment accumulated between them. If it were the best plan, it would also be the most expensive; but it is the worst. The current from the rising tide is sometimes flowing into the sea-opening between the jetties at times when the current from the bay is seeking egress. Even supposing the impossible case, of freedom of flow in both directions, coincidently with change of tide, no more water can obtain entrance for inflow than for outflow; whereas, what such channels need is preponderance of outflow for scouring purposes. Such constructions have been made along our coast, open to the prevailing drift of the region, or a single submerged spur-jetty has been placed in a similar position, athwart a channel. Thus is ensured, in the first case, speedy resort to dredging, in order to keep the channel free, and in the second, gradual submergence of the whole work in the sand. The first of the two projected jetties, intended to be protective of a channel, has actually been built to leeward of it, with what should have been the obvious consequence of the injury of the channel which it was the main object to conserve and improve. The two parallel jetties at the mouth of the Mississippi, the great engineering work of Captain Eads, are not in the same category with such works. The body of water represented by the Mississippi is a *vis viva*, a living power of great strength, having no dependence for energy upon current formed by rise and fall of tide. It rolls resistlessly in one direction, acting as a huge tool graving its way through the muddy bank which the waters of the Mississippi have through the centuries deposited in the tract known as its delta.

We Americans hold ourselves as a people intelligent and far-seeing

beyond any other nation of the earth, and yet it is thirteen years since the true method for treating certain of our Southern inlets was crowned, without adequate practical results, by the American Philosophical Society, and its discoverer has not yet been able to obtain, from the millions yearly disbursed by the Government on harbor improvements, a fair opportunity to demonstrate what some of the most experienced maritime engineers of the day regard as a great discovery. To give some idea of the difficulty which this inventor, Prof. Lewis M. Haupt, has encountered, it is only necessary to quote the concluding sentence of the Board of Engineers, U. S. A., in rejecting Professor Haupt's plan as of no value. "The views," it says, "are purely theoretical, are unconfirmed by experience, and contain nothing not already well known, which has a useful application in the improvement of harbors." This verdict is so self-contradictory, implying that there are in the views presented things that are well known as useful in the improvement of harbors, and yet explicitly stating that those views are purely *theoretical*, that one's faith in the carefulness of the examination by which the conclusion was reached may well be shattered. To cap the climax, an officer of the U. S. Engineers has stated that methods such as those recommended by Professor Haupt had been tried without success in several places ; but examination shows that the trials were either half experiments, or else, through inappreciation of the conditions precedent to success, were wholly misdirected.

Among other maritime engineers, however, who have examined into the jetty system of Professor Haupt, there is hardly a dissentient voice as to the value of his discovery. In the first place, his thesis on the Physical Phenomena of Harbor Entrances was, in accordance with the rules for application for the Magellanic Premium, sent by him anonymously to the American Philosophical Society. The committee to whose special examination it was submitted consisted of men of the amplest experience in field and office. The society, in a remarkably full meeting, confirmed the justness of their award of the prize medal to Professor Haupt for a discovery beneficial to mankind. Since then, distinguished engineers, George B. Roberts, J. E. Hilgard, Frederick Graff, A. G. Menocal, N. W. Eayres, Joseph M. Wilson, George Y. Wisner, Adolphus Bozano, Joseph J. deKinder, L. E. Gooley, H. C. Ripley, E. A. Gieseler, and the members generally of the American Society of Civil Engineers, have expressed their approval of Professor Haupt's system of the so-called "reaction jetty," in lieu of the present double jetty system. Nevertheless, as things stand, he has been unable to secure thorough trial on its merits before dispassionate judges, or by an unfettered construction, an opportunity for demonstration that it meets and overcomes difficulties heretofore regarded as insurmountable.

At length, however, a tolerably favorable opportunity to prove the

correctness of the system seemed to arise in the treatment of the inlet of Aransas Pass, Texas. To competent maritime engineers the success he there achieved under great difficulties is a perfect demonstration of the correctness of his views. The nearest anticipation found upon record of the correctness of this theory was the sinking of thirteen vessels which were scuttled on the bar off Charleston, S. C., during the Civil War, for the purpose of blocking up the entrance of the harbor.

For the correctness of the statement made as to the truth of this theory, reference is made to the latest map of Aransas Pass, executed by the Coast and Geodetic Survey in February, 1899. The depths thereon shown, when compared with those previously charted, give a good channel to the sea, except for the interruption athwart it of the spur-dike which had been abortively placed there for the deepening of the channel, and which had been reported as having "*disappeared.*" This statement was interpreted by those in charge of the subsequent work as meaning that the dike had undergone submergence in the sand to such a depth as not to interfere with the reproduction of the channel in its original natural position. In point of fact, the work, as designed by Professor Haupt, has more than accomplished what he had set out to do, notwithstanding the obstacle thus unexpectedly thrown in its way, and for which no provision had been made for removal. Let us now learn from the history of the work the difficulties which were overcome, despite the absence of financial support from the general Government, and despite the entanglement of the obstruction placed on the site under preceding administrations, and despite the unusual physical difficulties. The general Government, at the recommendation of the U. S. Engineers, decided, in 1889, to devote the whole appropriation by Congress for the West Gulf Coast improvements to operations looking to the betterment of the Galveston entrance. This afforded an opportunity for Professor Haupt to demonstrate the efficacy of his system at Aransas Pass, Texas, under private control. The Aransas Pass Harbor Company, having secured a franchise from the United States, was induced by Mr. Brewster Cameron, of Arizona, and Col. Geo. W. Fulton, of Rockport, Texas, after their previous attempts to improve the channel by other means had failed, to construct a portion of Professor Haupt's Reaction Breakwater in 1895, with the results already mentioned.

Aransas Pass is an inlet draining Corpus Christi, Aransas and Nueces Bays. The natural depths on the bar there vary from 6 to 8 feet. One of the difficulties to be contended with, arising from the fact that the rise and fall of the tide, which is diurnal, is but 14 inches, and the current generated thereby necessarily weak, is that it becomes imperative to concentrate the largest percentage of the tidal prism for the performance of the function of scouring the channel.

In 1869, the citizens of Rockport had placed a spur-dike of 600 feet in length on the north side of the Pass, thus protecting, in a measure, the channel beyond into the sea, and increasing the depth over its bar by 2 feet. This structure was, however, soon destroyed by storms. In 1870-71 the U. S. Engineers reported that the place was not susceptible of permanent improvement without great expense. In 1879, however, they made an estimate for the work, by which to secure a channel of 12 feet in depth over the bar. The construction for this purpose was to consist of two jetties. The work was begun in 1880, but, unfortunately, by placing a jetty on the west or wrong (because it is the leeward) side of the channel, and additionally in a wrong direction. In 1889, after an expenditure on the work of about \$500,000, it was suspended at a time when the depth shown over the bar was only 7.5 feet; decreased from 1887, when it was 8.5 feet. The original plan, with an estimated cost of over \$2,052,000, was calculated to secure a probable depth of 20 feet over the bar. In 1885, however, when the work according to the original plan had been extended in the form of a jetty for 5,400 feet, it closed, and in the course of seven years the jetty, which was a spur-dike, was reported by the U. S. Engineers to have "*disappeared*," which was everywhere interpreted to mean that the jetty had become embedded to so great a depth in the quicksands which those engineers had formerly represented as characterizing the bottom, that it was beneath the ordinary level of the bottom of the natural channel, athwart which it had passed on its course.

The Aransas Pass Harbor Company, chartered in 1890 by the State of Texas, obtained an Act of Congress in the same year, by which it was authorized to develop, at its own expense, a channel of 20 feet in depth over the bar. After some preliminary experiments which were unsuccessful, it began work on the Reaction Breakwater in July of 1895, and by the end of October of the same year there resulted 13 feet in depth, secured through the mere initiatory application of this system. It was then discovered, as the consequence of the great scour which had been effected in so short a time, that the remains of the old spur-dike, previously reported as having disappeared, crossed the whole width of the improved channel. This unexpected obstruction, with the failure of the contractor to receive money for work executed elsewhere, resulted in an entire suspension of the work, after he had removed a portion of the old jetty by dynamite. In this extremity the citizens of southwest Texas were impelled to request Congress to appoint a Board of U. S. Engineers to appraise the money value of the work accomplished, with a view of turning the property over to the Government, conditioned upon the immediate completion of the work. The Board appointed under this resolution reported, in the face of the evidence here briefly given, that the work was of no value to the Government. Such a conclusion

may be safely left to the reader's judgment for a verdict in favor of the Reaction Breakwater as tested in the face of the greatest difficulties.

Thus, after a large expenditure by private enterprise, has a work been brought to a close by an accident for which its promoters and director are in no wise responsible. The U. S. Engineers reported immediately after its stoppage, a channel over the bar of only 8.5 feet in depth, but their own accompanying map shows, in the thread of the stream, a depth of 9.25 feet; but this is not all. Stranger still is the fact, not subsequently reported by them, that where, in the map of 1879, just referred to, only 8.5 feet are shown, the late Coast and Geodetic Survey Chart of 1899 reveals over 22 feet in depth. When it is considered that this result has been accomplished there for the first time by a Reaction Breakwater, even in an uncompleted condition, and with a transverse obstruction midway of the current in the channel, it may be well said that Professor Haupt's system for the treatment of such channels has fully vindicated itself in producing such results as those shown in the teeth of the obstacles thus described.

It now only remains, in conclusion, to describe the characteristics of this system, involving the theory upon which it was designed and the mode in which experience shows that it effects its purpose. The fruit of the study of the problem involved, both at home and abroad, and all observations since the first publication of these views, combine to prove the absolute correctness of the conclusion reached in the report.

The Reaction Breakwater is placed immediately to windward of the channel to be protected. It is placed more or less in the natural trend of the channel in the form of a compound and reversed curve. It leaves an open space between the head of the jetty and the land. At its head it flares somewhat away from the channel. This last feature of the construction enables the rising tide to find entrance through the inlet of the bay by means of the opening between the head of the jetty and the land, as well as by the mouth of the channel over the bar. At falling tide the water of the bay, passing through the inlet, follows close to leeward in the jetty, added to by water flowing through the opening of the jetty, which, obedient to the greater momentum of the main stream flowing out of the channel, increases by its volume the effectiveness of scour.

In speaking as follows of the windward and leeward sides of the channel, reference is made only to the annual resultant of the forces along the particular shore under consideration. Placed just to windward of the channel, the breakwater protects it from the material arrested, thus making a protective barrier for the channel, increasing in hardness as time goes on. Back of the landward end of the breakwater, where it flares away from the channel, the form of construction ensures the accumulation of a bank of sand outside of the jetty—the physical resultant of sand accumulation along the line of inertia represented by

the outside of the jetty and the mild inflow of the water between the head of the jetty and the land.

A second parallel, or approximately parallel, breakwater is not requisite to protect the channel, but, as has been said, is objectionable, as entailing less scour than is procurable in the channel, the necessity of constant dredging, and therefore great cost. The direction any channel primarily assumes represents the character of the soil and the resultant of the forces of building and erosion to which it is subjected by nature. It therefore requires for its possible improvement new distribution, on the one hand, of those forces, and on the other hand protection for material on which those forces in their new distribution are exerted. Thus the intervention of man may secure through a new resolution of forces changes in nature better fitted for his purposes. Nature and man, as already intimated, may sometimes join effectively to produce the best possible transmission of energy for given conditions. The conditions will, of course, vary indefinitely in details, but can never involve violation of the principle long since known and utilized.

The claims of Professor Haupt, as originally defined in his paper on the "Physical Phenomena of Harbor Entrances," and as distinctly set forth in his present application for an examination into them by the Committee represented by the undersigned, are fully confirmed by the investigations which this Committee has given to the subject. They may be briefly summarized as follows :

(1) *The form and position* of the breakwater, with reference to the available forces.

(2) *The results* already secured by the partial control of these forces, as shown by existing work at Aransas Pass.

(3) *The economy of time and money* due to the utilization of the energy of the ebb currents, and the protection of the channel from littoral drift.

(4) The construction (formation) by natural agencies of a *counter-part* to the breakwater in the form of a sand-spit or barrier on the lee side of the channel *without cost*.

(5) *The construction and maintenance* of a channel by natural agencies, *without dredging*, in the face of unusual difficulties.

(6) *The lateral displacement* of the material of the bar without sensible *advance seaward*.

(7) In short, the unprecedented economy per foot of depth gained in time, and work accomplished, without expense for maintenance by dredging, marks a distinct advance in maritime engineering.

The literature of this subject of the claims of Professor Haupt to a discovery of the best treatment for certain channels is now somewhat voluminous. We would respectfully recommend its study to our countrymen who are desirous of acceptance of the most advanced

thought on any subject that may be promotive of the economical administration of maritime work, or that may redound to national reputation, or that may even look no further than the doing justice to a single citizen. Especially would we recommend, upon the basis of the record (only a fragmentary portion of which could be here given), to committees of Congress, an appropriation for national public works, and to men generally of national prominence and influence examination of this important subject. It is well known that radical changes in any procedures among men rarely emanate from bodies possessed of the ground by prescriptive right from time immemorial.

For the same cogent reasons which we, the undersigned, have not hesitated to entertain and to present in favor of Professor Haupt's system, as promotive of the best interests of maritime construction on alluvial coasts, we hereby award him, for what we regard as his extremely original invention, the silver medal and diploma of the National Export Exposition, the highest testimonial in our power to grant.

Additionally, we would respectfully refer to the Franklin Institute, requesting that this subject be placed before its Committee on Science and the Arts, with the view to their appointing a jury to consider the expediency of making a further examination of and award to this meritorious invention.

(Signed)

R. MEADE BACHE, Chairman.

AMBROSE E. LEHMAN.

JOHN E. CODMAN.

JOHN HAUG.

THE ELECTRO-CHEMICAL INDUSTRY IN FRANCE.

The following abstract of a paper by J. B. C. Keershaw appears in the *Electrical Review*: Eleven electro-chemical and electro-metallurgical works have 54,000 horse-power derived from waterfalls. The number of electrolytic copper refineries is eight, and it seems improbable that this industry can develop in France, on account of the scarcity of raw copper suitable for refining. There are two plants for the production of aluminum, one with 5,000 horse-power at Le Praz, using the Heroult process, the other with 4,000 horse-power at St. Michel, using the Hall process, but not all of the 4,000 horse-power are used for the production of aluminum. Chlorate is made at St. Michel, under the patents of Gall and Mortlaur, cells without diaphragm being used with platinum electrodes. Chlorate is also made by a similar process at Chedde, where 12,000 tons are available. The calcium carbide industry has developed to a greater extent in France than in any other European country. A modern estimate of the power available in the twenty-six carbide factories places it at 50,000 horse power. The growth of the alkali and chlorine industry has been slow. It is possible that early in 1902 there will be four electrolytic alkali works. Ferro chrome, ferro-silicon and other similar alloys are produced in electric furnaces at several places. The pro-

duction of ozone by the silent electric discharge through air, and the use of this ozonized air for sterilizing water, for oxidation purposes in the manufacture of perfumes, and for aging wines and spirits, have received much attention in France. In only one case has a practical success been achieved, namely, in connection with the manufacture of heliotropine and vanilla. The Verley ozonizer is used in this plant, near Paris, and 10,000 kegs of the two products named are produced per year. The experiments, made with the Hermite sewage disinfecting process at Havre and Marseilles, about 1890, have not led to any practical success. This process, in which electrolyzed seawater was used, resembled the Wolff process tried at Havana in 1899, and failure in each case was due to excessive cost.

DAMAGE TO OVERHEAD WIRES BY SLEET STORMS.

The *Electrical World* makes the following editorial comments on this topic :

The damage inflicted upon overhead wires of every description by the sleet storm of the 21st of February exceeded previous records. For several days Philadelphia was telegraphically isolated from the rest of the country as completely as though invested by a besieging army. Baltimore was in nearly as great a predicament, and even New York was crippled in its telegraphic communication with the outside world. Such a condition had not been confronted for half a century. In order to produce such disastrous conditions it is necessary that the air lying close to the surface of the earth should be below 0° C., while the superincumbent strata should be relatively higher in temperature. With precipitation in the form of rain, congelation then occurs upon the incident surfaces, and each wire may become the axis of a cylinder of ice. Telegraph and telephone wires went down for miles. On the Pennsylvania Railroad the poles beside the track were in places carried away, broken, or upturned by the dozen together, and where the poles stood, the cross-arms were often torn away. Where both poles and cross-arms held their own, the wires were broken in many instances. Electric light wires, being generally larger, suffered less, and trolley wires least of all, save where broken trees and poles fell across the road. The forests were injured for hundreds of square miles. The Atlantic coast was involved in this storm from Maryland to Connecticut.

The question arises whether, in view of the enormous cost of restringing the destroyed lines of wire, it would pay to carry the wires in the open country underground. In large cities the wires are buried already. This is a very large question, involving great outlay and engineering difficulties. It is a question of engineering economics. It would seem, however, that under existing conditions it would not pay to bury the wires at large. While the buried wires would be sheltered from sleet, they would be at the mercy of pick and plow. Wherever a wire runs, through earth, water or air, its continuity is threatened by special dangers, and immunity is a mere matter of degree. Moreover, there would be enormous expense in making and laying the wires and relatively large expense in repairing them, although repairs might be less frequent. The buried wires would be very much slower in transmission than the overhead wires, and the cost of transmission would be increased.

THE FRANKLIN INSTITUTE.

A lecture delivered at Association Hall, February 8, 1902.

The Gases of the Atmosphere.*

BY DR. H. F. KELLER,
Member of the Institute.

(Concluded from vol. cliii, p. 430.)

The atomic theory of Dalton, which had just been announced to the scientific world, moreover, required that the elements contained in a compound should be in the ratio of either their atomic weights or of simple multiples of these. If this were true of air, then there should have been found 22.2 per cent. of oxygen by weight instead of the 23 per cent. which it contains.

Again it had been observed that when two gases combine with each other, there is either a rise or fall in temperature, and generally a contraction of volume, but no such changes were noticeable when air was artificially made by mixing its constituents in the proper proportions.

It was evident, then, that air is a mixture and not a compound.

Nor is the composition of air absolutely constant. By the aid of more refined analytical methods than had been employed before that time, Bunsen, in 1846, succeeded in detecting slight variations in the percentage of oxygen in samples of air collected in different places and at different times. His figures vary between 20.84 per cent. and 20.96 per cent., and they have been abundantly confirmed by later investigations.

It requires but little reflection to convince us that the composition of air cannot remain constant, and that other gases besides those I have mentioned must be present in it. Consider the many agencies constantly at work to deprive

* In the preparation of this lecture free use has been made of the standard works on the history of chemistry, and especially the writings of Professor Ramsay on this subject.

the atmosphere of its oxygen—the respiration of man and animals, the burning of fuel, the decay of animal and vegetable matter, to mention but a few—and consider, too, the many gases which are generated on this earth of ours, and find their way into its atmosphere. Must we not fear that the air we breathe will in time become so poor in oxygen and so rich in other gases as to threaten our existence?

There is little doubt that even a slight diminution in the proportion of oxygen would seriously affect all living beings, as they are constituted at present, but you need entertain no fears of an impending oxygen famine, or that the human race will some day be snuffed out as our taper was by the accumulation of carbonic acid in the air. The oxygen consumed in various ways is, in a large measure if not entirely, restored to the atmosphere by the green plants which, under the action of the sunlight, assimilate the carbon of carbonic acid and reject the oxygen it contains. But even without this compensating factor, the shrinkage in our supply of oxygen would be almost inappreciable. It has been estimated that, allowing for the oxygen consumed by man and animals at the present rate, and counting that required for combustion as four times this amount, it would be 8,000 centuries before the atmospheric reservoir would be depleted.

To give you some idea of what that means, let us imagine the atmosphere to be contained in a huge vessel, and this vessel hanging from the arm of a gigantic balance; we would have to place upon the scale-pan on the other side 140,000 cubes of copper, each one mile on edge, to counterpoise the air; then, supposing oxygen to be drawn from the vessel at the rate before stated, the total weight would be diminished in a century by not more than four or five of the copper weights.

As to the carbonic acid contained in air, its proportion, too, remains nearly constant—about 3 parts in 10,000. Although this seems very little, the aggregate amount is stupendous; it suffices to supply the entire vegetable world with its carbon.

Huxley has calculated that a section of the atmosphere

resting upon a square mile of the earth's surface contains no less than 13,800 tons of carbonic acid, an amount which is sufficient to furnish the carbon for a small forest of trees weighing 7,400 tons.

In addition to the gases which were discovered in the atmosphere during the pneumatic period, quite a number of other constituents, mostly in very minute quantities, have been detected by the chemists of the nineteenth century.

Among them is a curiously modified form of oxygen, known as ozone. It was first obtained in 1840, by Schoenbein, who showed that it exists in air. It differs from ordinary oxygen chiefly in being far more active, and in possessing the power to destroy noxious gases and germs of disease. Its purifying effect upon the atmosphere, however, has been greatly overrated, for its amount does not exceed one part per million.

Air also contains traces of nitrous and nitric acids, partly combined with ammonia. It is from these nitrogenous compounds that plants derive much of the nitrogen they require for the development of their structure and fruit, the free nitrogen in the atmosphere not being available for that purpose, except in some special cases.

It now remains for me to tell you of the achievements in atmospheric chemistry during the last eight years.

Previous to 1894 it was the general belief among scientific men that the composition of air was certainly one of the subjects upon which their knowledge was most complete. This belief, however, was rudely shaken by the announcement in that year, by Lord Rayleigh and Prof. William Ramsay, that a new gaseous element had been discovered by them in what was supposed to be *pure* nitrogen obtained from air. The great interest awakened by this unexpected find was greatly enhanced when it developed that the stranger, being entirely devoid of chemical affinity, could not be received into any of the old-established families of elements. Owing to this unique character, or rather lack of character, it was given the name of *argon*, the idle one.

Truth is often stranger than fiction, even in science. An account, more fascinating than any of Jules Verne's plausible inventions, might be written of the discovery of argon, under the title perhaps of "The Triumph of the Third Decimal." As I have not the skill of a raconteur, I must be content to recite the principal incidents connected with this discovery.

In one of his great memoirs, entitled "Experiments on Air," Cavendish described the effect of electric sparks upon a measured volume of air, in the presence of caustic alkali, and confined over mercury. You recall the picture of the apparatus I showed on the screen. He noticed that the gas contracted in volume, and, on successively adding small portions of oxygen, while sparks continued to pass, he found that the volume was further diminished, until finally only a small fraction of the gas remained. He ascertained the cause of shrinkage; under the influence of the electric discharges, the nitrogen combined, first with the oxygen of the air, then with the added portions of oxygen, and the resulting oxide of nitrogen was absorbed by the potash, forming potassium nitrate or nitre. The residue, after the excess of oxygen had been removed from it, "certainly was not more than $\frac{1}{120}$ of the bulk of the phlogisticated air (nitrogen) let into the tube, so that if there is any part of the phlogisticated air of our atmosphere which differs from the rest, and cannot be reduced to nitrous acid, we may safely conclude that it is not more than $\frac{1}{120}$ part of the whole." No attempt was made by Cavendish to find out what the residue was, and more than a century elapsed before this problem was solved.

In 1883 Lord Rayleigh, the celebrated physicist, was greatly puzzled by the observation of a difference in the densities of two specimens of what he believed to be pure nitrogen; one of the specimens which had been made from ammonia (a compound of nitrogen and hydrogen) was lighter than the other, which had been obtained from air. The difference was small, but distinct; 201 measures of the "chemical nitrogen" were found to weigh as much as 200 measures of the atmospheric variety, and many careful

repetitions fully established this difference in the third decimals of the densities. The first explanations to suggest themselves were that either one or both preparations of the gas contained some impurity, or that the atmospheric nitrogen might have been somehow partly converted into a denser modification, differing from ordinary nitrogen as ozone differs from ordinary oxygen.

But a most searching investigation failed to reveal the presence of even traces of any other known gas in either one of the nitrogen preparations, nor was it possible to obtain the slightest evidence that the atmospheric gas had been modified in any way.

The attention of chemists had been invited by Lord Rayleigh to the strange anomaly that the same gas had two distinct densities; but no one responded by offering an explanation. Professor Ramsay now asked permission to try some experiments on the nitrogen of the air, and his request was readily granted.

Having observed that *magnesium* slowly absorbs nitrogen, when the gas is passed over red-hot chips of the metal, he proceeded to apply this experience to some nitrogen which he had prepared from air by carefully removing all the oxygen, moisture, carbon dioxide, etc. As the volume of the gas diminished—the absorption being exceedingly slow—the density was found to increase. This encouraged Ramsay to repeat the experiment on a larger scale, and, by the aid of an elaborate apparatus in which the gas was made to circulate for many days over the heated metal, he succeeded in absorbing all but a very small residue, which proved to be nearly half again as heavy as nitrogen. To make sure of the complete removal of the latter gas, he mixed the residue with oxygen, and, taking advantage of Cavendish's experience, exposed the mixture to a rain of electric sparks in the presence of caustic soda. Further contraction ensued, and, when the excess of oxygen was finally removed, a gas having a density twenty times as great as that of hydrogen, and one and one-half times that of nitrogen, remained.

The next step was to ascertain whether this gas contained any of the known elements, and the best way (the only way,

in fact) to do this was to make a spectroscopic examination of it.

The spectroscope, as has been explained in a previous lecture of this course, is an instrument consisting of prisms and lenses so arranged as to separate the various kinds of light into their components and permit the examination of these components. Under proper conditions every element emits a light which is peculiar to it. Thus, when gases in a rarified condition are subjected to the discharges of an induction coil, they glow and send out rays of different colors, which, viewed through the spectroscope, betray the chemical nature of the gases. To this end, the specimens to be examined are enclosed in glass tubes provided with platinum wires at both ends and contracted in the middle to a fine capillary—Pluecker's tubes, as they are called after their inventor. On connecting the wires with the terminals of a coil, the electric discharge passes through the gas, and the glow appears most brightly in the capillary part of the tube.

Here, for instance, is a Pluecker-tube containing hydrogen, which gas we instantly recognize by three characteristic lines in its spectrum : one red, one blue, and one violet.

Ramsay's new gas still contained nitrogen, for it showed the numerous bands which characterize this element ; but it gave in addition many other lines, mostly red and green, which could not be identified with those of any known element.

While these experiments were in progress, Lord Rayleigh was engaged in repeating Cavendish's experiment of sparking atmospheric nitrogen mixed with oxygen in the presence of caustic alkali. His results confirmed Cavendish's statement that a small, unabsorbable residue finally remains, and also proved that this residue is proportional to the volume of the nitrogen experimented upon. He, too, noticed the peculiar spectrum of the new gas.

The two discoverers now agreed to go into partnership to complete the investigation, and to make a preliminary announcement of their discovery of a new element in the atmosphere.

By means of improved apparatus they were able to isolate argon from air in considerable quantities, and to obtain it free from nitrogen. Its exact density was determined at 19°94, and its spectrum was carefully studied and mapped. The other physical properties, too, were very fully determined, but nothing remarkable was noticed about them, except the rate of speed at which sound travels in this gas. The velocity of sound in a gas is influenced by the greater or less complexity of the smallest particles or molecules of that gas, and the velocity of sound in argon proves that its molecules, unlike those of the more common gaseous elements, which consist of two atoms, are single atoms. In other words, the molecule and atom of this element are identical.

But it is from a chemical point of view that argon presents the greatest interest. It differs from all the elements previously discovered in that it is absolutely devoid of chemical activity; no means at the command of modern science has been left untried to coax it to combine with other elements, but it has steadfastly maintained its freedom. Neither prolonged exposure to the most powerful electric discharges, nor contact with the most chemically active substances, such as fluorine gas, evoked the slightest response of a chemical nature.

Science is knowledge reduced to system. The more advanced our knowledge grows, the more comprehensive, as a rule, will be the system. Not only does such a system then permit an orderly arrangement of the known facts, but it will also provide, to a great extent, for the fitting in of new discoveries; indeed, these can often be foretold from gaps in the system. The progress of chemistry during the nineteenth century has made it possible to formulate a comprehensive scheme, known as the periodic system, in which all the known elements have found a place, and in which the existence of certain gaps has led to the prediction and subsequent discovery of other elements. Gallium and germanium, for instance, were discovered years after their existence had been predicted, and they have been found in every important detail to answer to the elaborate

descriptions which Mendeljeff, the author of the periodic system, had given of them.

But the discovery of argon had not been thus prognosticated. After its physical and chemical character was ascertained, Ramsay was very anxious to find its place among the other elements. Inasmuch, however, as it shows no resemblance to any of the members of the groups which constitute the system, there was no gap in these groups into which it would fit, and it seemed for a while as if a serious defect in Mendeljeff's system had been uncovered.

This difficulty served as an incentive to Ramsay to continue his investigation, and thus led him to the discovery of the "companions of argon," four inert gases resembling argon and, like it, constituents of air.

Although all efforts to produce compounds of argon had been in vain, Ramsay believed it possible that such compounds might exist in nature, and he instituted a diligent search for sources of the gas, other than the atmosphere. He found that it is contained in most natural waters, dissolved with the other atmospheric gases. His attention was further directed to a remarkable observation which had been made in the laboratory of our Geological Survey, in Washington, by Dr. Hillebrand. On treating the rare uranium mineral, *cleveite*, with sulphuric acid, this chemist had obtained a colorless gas, which he believed to be nitrogen. Ramsay procured considerable quantities of the mineral, and extracted the gas in the hope of detecting argon in it. After removing nitrogen in the manner already described, he made a spectroscopic examination of the remaining gas. To his great surprise, the lines he observed, though very brilliant, were not those he expected to see, but those of an element for which chemists had vainly been searching this earth for many years. It was during the eclipse of 1868 that a French astronomer, Janssen, had noticed these lines in the spectrum of the sun's chromosphere, and they had been attributed by Frankland and Lockyer to the presence of an unknown element, to which the name helium had been given, from helios, the sun.

The existence of the supposed solar constituent was thus

proved, and no time was lost by Ramsay in acquainting himself with the character of the welcome visitor, who had so narrowly escaped making his terrestrial debut on this side of the Atlantic. It turned out that helium bears the closest resemblance to argon. Like the latter, it is an inert, colorless gas, and its molecules, too, are single atoms. But it differs from argon, not only in its spectrum, but in density; it is only one-tenth as heavy, and, next to hydrogen, the lightest substance known. Of all gases it is the most perfect, and the only one which has not as yet been reduced to the liquid state.

The pronounced resemblance in their properties, together with the relation observed between their atomic weights, made Ramsay suspect that helium and argon are members of a more numerous family of elements. In an address he delivered in 1897 on "An Undiscovered Gas," he ventured this remarkable prophecy: "There should, therefore, be an undiscovered element between helium and argon, with an atomic weight sixteen units higher than that of helium and twenty units lower than that of argon, namely, twenty. And, if this unknown element, like helium and argon, should prove to consist of monatomic molecules, then its density should be half its atomic weight, ten. And, pushing the analogy still further, it is to be expected that this element should be as indifferent to union with other elements as the two allied elements."

A systematic search for this hypothetical element was at once begun, and, after many unsuccessful experiments, the missing link was found, the prediction being fulfilled in every particular.

A new invention furnished the means to this end. I have mentioned that gases can be converted into liquids; it is done by either cooling or compressing them. In some cases liquefaction takes place easily, that is by lowering the temperature only a little or by moderately increasing the pressure, while in other cases the gas must be exposed to very intense cold, and a great pressure applied at the same time. The liquefaction of air, for instance, can only be accomplished by reducing its temperature to, say, 300

degrees below zero, and applying a pressure of about 500 pounds to the square inch. Until 1895 such conditions could be brought about only at great expense, and the liquefaction of air and other difficultly liquefiable gases had been conducted on a small scale by a few skilful experimenters. In that year, however, a process was invented by which air can be liquefied at small expense and in considerable quantities.

Of two machines designed for this purpose, the one constructed by Dr. Hampson was used by Ramsay and his assistant, Dr. Travers, to prepare large amounts of liquid air, for the double purpose of using it as refrigerant in liquefying argon and to see whether the liquid argon or the liquid air itself would not yield up some of the undiscovered element.

The results surpassed all expectations; on distilling the liquid obtained from about 4 gallons of argon gas, it was found that a gas lighter than argon passed off with the first portion distilled; and, on slowly boiling away the liquid air, gases heavier than argon were obtained from the last portions.

The spectroscope was again called to aid, and no difficulty was experienced in recognizing three distinct new elements. The light gas from the argon emitted a brilliant red light when sparked in the Pluecker tube, and received the name *neon* (the new one), and of the two heavier ones obtained from liquid air one was called *krypton* (the hidden one), and the other, *xenon* (the stranger), the former being characterized by a yellow and a green line in its spectrum, the latter by a very complex spectrum in which blue lines are most conspicuous.

Time does not permit my dwelling longer upon the progress of this wonderful research; suffice it to say that Ramsay and Travers have succeeded in separating the companions of argon from air and from each other, in determining their principal properties, and in estimating approximately their proportions in the atmosphere.

The very close resemblance which the five new elements bear to one another, and the very regular manner in which

their physical properties vary, make it certain that they constitute a natural family, which, as Professor Ramsay has lately pointed out, fits perfectly into the periodic system, forming a connecting link between the elements of extreme positive and negative activity.

Their relative amounts in air are estimated to be :

937 parts of argon per hundred.

One or two parts of neon per hundred thousand.

One or two parts of helium per million.

About one part of krypton per million.

About one part of xenon in twenty million.

You would doubtless like to know the function of these inert gases in the atmosphere, their *raison d'être* in nature. I regret to say that, so far as we can see at the present time, they serve no useful purpose. Oxygen is the life-sustaining principle that keeps everything going on the earth; nitrogen restrains the activity of oxygen within proper bounds; carbon dioxide, ammonia, nitric and nitrous acid are necessary for the growth of plants; vapor of water plays a main part in those important and never-ceasing changes which we call the weather, and even ozone contributes its share of usefulness in freeing the atmosphere from deleterious matters, but no apparent benefit to the living world can be instanced as a result of the presence of argon and its companions in air.

While this seems an unsatisfactory admission with which to conclude our story, let us bear in mind that, after all, we know but little of the secrets of nature, and that future investigations will continue to alter and enlarge our views.

THE TUNNEL BETWEEN SCOTLAND AND IRELAND.

The proposed railway tunnel between Scotland and Ireland, judged as one element of the general scheme or schemes which are now being mooted for shortening the distance of the ocean passage between Europe and America, is placed in somewhat the same category as the late Austin Corbin's dream for the creation of a great terminal port at Montauk, at the eastern end of Long Island; there being this difference, however, that when judged on that ultimate basis to which all such schemes must come—financial practicability—the Scotland-and-Ireland tunnel is even less feasible than Corbin's project. The cost of the tunnel is estimated by the contractors at \$50,000,000, exclusive of

interest, and, as matters now stand, there is not nearly sufficient traffic, either freight or passenger, to enable the scheme, if completed, to earn interest on the cost of construction. Nevertheless, in view of the rapid growth of commerce and the vast accumulation of capital seeking investment, it is conceivable that conditions may arrive in some future day that will guarantee the construction of a thirty-four and one-half mile tunnel such as this.

The engineering features of the tunnel were discussed recently in a paper read by James Barton, M.I.C.E., before the International Engineering Congress at Glasgow. Of the three possible locations for the tunnel, the one selected lies between Wigtonshire, Scotland, and the Irish coast, at a point where the distance from shore to shore is within twenty-three miles. The maximum depth of water varies, according to the line selected, between 480 and 900 feet. The route forms a through line between Carlisle and Belfast, and has the advantage of providing the best route from Scotland to the whole of Ireland, and from the north of England to Ireland. The survey for the tunnel proper commences five miles from Stranraer railway station and finishes five and a half miles inside the shore line of the Irish coast, the total length of the tunnel being thirty-four and a half miles. Leaving the tunnel, the line extends for ten and a half miles to the city of Belfast. The total length from Stranraer to Belfast is fifty-one and a half miles, thirty four and a half of which is tunnel, and twenty-five of it beneath the sea. The roof of the tunnel is 150 feet below the sea bottom. The proposed heading is 7 feet high by 10 feet wide. It is expected that the portion of it which is driven through the Silurian will be cut as rapidly as the Simplon tunnel, while progress through the Keuper marls is expected to be more rapid. It is estimated that the whole of the heading would be completed in less than ten years, and the tunnel finished in about twelve years. This estimate is based upon a comparison of the speed of driving four notable tunnels. The Mont Cenis was driven at the rate of 6 yards a day, and at a cost of \$1,120 per yard. In the St. Gothard the maximum speed was 10 yards a day, at a cost of \$710 per yard. In the Arlberg the maximum speed rose to 12 yards a day, while the cost was reduced to \$535 per yard; and it is expected that on the Irish tunnel, judging from the quality of the material to be passed through and the improved methods now being used on the great Simplon tunnel, the speed will be increased and the cost per yard reduced still further. As to the question of water entering the tunnel, although the uncertainty on this point is admitted, the author of the paper does not consider that the difficulty will be a serious one. No water leakage in any great quantity occurred during the construction of the Severn or the Mersey tunnel, at least in those portions of these tunnels that were immediately beneath the sea; and it is believed that the sea bed below the Irish tunnel has probably closed all faults in the rock sufficiently to keep out sea-water in any but easily-handled quantities. The line will be operated electrically from power stations located near the main shafts at each end of the tunnel; and it is proposed to run trains at a speed of sixty to seventy miles, thereby reducing the time in the tunnel to about half an hour.—*Scientific American*.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, February 19, 1902.

President JOHN BIRKINBINE in the chair.

The Metric System of Weights and Measures.

(Continued from vol. cliii, p. 418.)

CORRESPONDENCE.

[The following letters have been received by the Secretary and by the Committee as contributions to the discussion of the report. In some instances these have been edited by the omission of irrelevant matter.—THE SECRETARY.]

WILLIAM SELLERS & CO., INCORPORATED.

PHILADELPHIA, March 20, 1902.

To the Secretary.

DEAR SIR :—The report of the special committee of the Franklin Institute is probably based upon the answers received to the "questions discussed at the meeting of sub-committee, January 17, 1902."

These questions appear to me to be very inadequate for the gravity of the subject under consideration. The concluding resolution of the special committee invites the National Government to force the metric system upon all of its departments as rapidly as may be consistent with the public service. This may mean something or nothing, as it can scarcely be for the public service to adopt a system of weights and measures in advance of the ability of the country to supply the raw material it requires in accordance with the new system.

The disadvantage of the French metric system is, that it is an attempt to measure time, space and matter decimally, whereas the decimal system is only specially adapted for computing numbers.

Believing, as I do, that for this country to adopt the French metric system would be an error of the gravest character, I submit herewith a series of questions that each reader may consider and answer for himself, so as thereby to arrive at an opinion concerning weights and measures based upon considerations other than that of uniformity with the foreign countries which have adopted the French system.

(1) Assuming the desirability of an international standard of weights and measures, is it so desirable that we should abandon for it all of our

engineering literature, all of our small tools, standard gauges and screw-threads now based upon our standard inch, all of our rolling-mill rolls, with all other special machinery for the preparation of raw material for the mechanical engineer, all of our binary divisions in common use and our binary division of our decimal monetary system?

(2) Assuming the advantages of the metric system for purposes of computation, and as the length of the French meter is not a necessary part of the system, would it not be desirable to adopt a metric system for this country with a length for the meter of 40 inches, whereby 25 mm. would exactly equal 1 inch, with measures of weight and capacity based on this meter as in the French system, so that the system could be used decimally or by whole numbers and fractions as in our monetary system?

(3) As such a system need make no change in our measures of length or in our fractional divisions of length and measures, and would afford the advantages for computation claimed for the existing metric system, would such advantages compensate for the small divergence from the French system?

(4) If they would not, then we are asked to abandon all that we have of weights and measures and our engineering literature based thereon, to adopt a foreign system for the sake of uniformity alone. Would any possible gain compensate us for the cost and confusion of such a change?

(5) Would any advantages claimed for the metric system compensate us for abandoning the standard inch and our fractional and decimal divisions of it, with our engineering literature based thereon?

(6) Would the advantage of a system which could be used decimally and duodecimally, if adopted by us, induce foreign countries to ultimately adopt our system?

(7) The use of the metrical system is now permitted in the United States; if it is so much better than our own, should it not gradually displace our system?

(8) If our export business should largely increase to metrical countries, with whose measures such exports might have to conform, would not this introduce the metrical system into our country without friction and without special legislation?

(9) Should the National Government pass any bill to enforce the use of the French metrical system in any of the departments of government?

Yours truly,

WM. SELLERS.

To the Secretary of the Franklin Institute :

The subject seems to me hardly to require or to permit any extended discussion. It has been familiar to the world, as a question of import-

ance in economics and the industries, in science and in art, for a century, and the system has become general all over Europe and throughout the world, except in the United States, Great Britain and their colonies; in some cases it is used in these countries, and in others generally in their dependencies. The advantages and relative disadvantages of its adoption are perfectly well understood and have been illustrated by every nation which has accepted it. No nation now enjoying its advantages could be induced to exchange it for our heterogeneous "system" of weights and measures—our no-system, rather—and the testimony in its favor from those who have had experience and are best entitled to give trustworthy evidence is practically unanimous. The only voices against either the system itself or its adoption are usually raised where that experience has not been had. It is making progress, slow to be sure, but none the less steady, in our own country and in Great Britain. The question is not, after all, on its adoption, but rather regarding the time and the rate of advance toward its installment as a national and officially accepted system.

A "free country," such as ours, perhaps mistakenly, is supposed to be, is at some disadvantage beside the autocratic or monarchical and the bureaucratic country in its inability to force upon individual citizens even the most desirable of improvements, and we must probably assume that the progress of this great movement cannot be greatly forced and that it must advance as people can be brought to see its usefulness in the individual case. It can probably only be accelerated by suasion, not by force. It must be by missionary work rather than by legal enactment. The statute must probably follow general voluntary use of the system.

In our country the mob may sometimes dominate the public in the city and lynch-law may prevail in the darkest country districts; but deliberate compulsion of the people through the law is not likely to be successful, even in so good a cause. A man may not be free to work where he chooses and when he chooses and for what pay he chooses, to make his own bargain or to select his own vocation in a so-called "free country;" but he will insist that he shall at least be permitted to weigh and measure in feet, inches and barleycorns, in bushels, pecks and various sorts of gallon, and in ounces, pounds and tons of 2,240 or of 2,000 pounds, as he may see fit, rather than adopt a decimal system that will save him time, trouble and nerve-strain and prolong the life of his children, or which will, in business, decrease cost and increase profit and promote accuracy and interchangeability and in the world's intercourse facilitate all commercial and financial transactions.

The resolutions presented for our consideration by our committee are most reasonable and conservative, and will not, I imagine, provoke much opposition. That last saving clause will reconcile all views and unite all parties. I do not see, however, how they could make their

action more radical under the circumstances. The system must probably make its way on its own merits, and I suspect that any attempt to force its introduction at a higher rate of speed would simply awaken otherwise dormant opposition and retard the movement seriously. An exasperated opponent will be active, energetic, persistent and industrious; a mildly favorable protagonist will be worth less in the contest than the utterly indifferent. The interested opposer of any statute proposed will count for more than will a dozen of the other sort on the other side.

There would seem to be no reason, however, why the National Government and its departments should not take advantage of the present situation, and availing themselves of their legal option, push the adoption each year sensibly further and into new divisions of their work. The equivalent measures in the older system should be retained and probably must be for a generation still to come; but the metric system should be the standard, not the British. The departments, in making their computations, could and should usually employ the metric system, and at the close of the work express the final result in metric quantities with the equivalent British no-system value placed after it in parentheses. Where the details of computations are given, they should be given in metric, rather than British terms and figures.

In scientific work, it is desirable that, as in fact is now usual, all work should be performed and all results given in the metric measure and no equivalents need be stated. In the applied sciences, where the man of science and the man of business are alike interested and are necessarily in communication, the equivalents should always be given until, in some perhaps distant period, the latter as well as the former has come to think as well as work with the simpler and more economical system and is at least as familiar with it as with our cruder muddle of measures of to-day.

In the points of contact of the governmental and of the scientific departments with the business world, it would be perfectly easy, if they chose, for the officials responsible for contracts to call for bids in most cases with metric measures given in the specifications, and, where it might be obviously practicable, to have their requirements stated in metric measures on every drawing and every specification. While it would be impracticable to-day to secure such a change in the purchase or construction of many standard machines and interchangeable parts, there are already many things which may be obtained on a metric specification and the number is constantly increasing. This custom on the part of Government and its departments and of scientific men and their departments would do much to facilitate the advance proposed. Much discretion would be necessary in this matter; but I think it would be entirely practicable.

Once the system becomes sufficiently generally known and its merits revealed by moderate extension of its use, the people of the United States may be relied upon to adopt it very quickly. The difficulties are mainly those which meet us in our attempts to secure any other sort of action by the people or their representatives. It comes of the primary difficulty of securing their attention and obtaining an opportunity to demonstrate the facts. The rapid introduction of the Australian system of ballot, once the people and their legislators had been brought to seriously consider it, the now rapid progress of the voting machine, the introduction of technical education and scientific professional training, the progress of forestry and a hundred other movements illustrate the point which I make here. The flow of the current of progress with us is like that of a stream through the gravel of the plains. It cannot be forced to a rapid permeation; but gravitation is always working and never is there an instant's cessation; it is only a question of time when the stream will find its way through to a clear course. There is a powerful gravitation working as constantly to urge the advance of this, as of every other, recognized improvement and we may be sure that if we simply clear away obstacles as we have the opportunity and open the channel here and there as we may, gravitation will surely, and in time rapidly, distribute the flow to all parts of the land and into every division of our industries.

It must not be forgotten, however, that our manufacturing industries have to-day become enormously extensive and that they constitute the fundamental element of our industrial system; even the art of agriculture having now become largely dependent upon mechanism and almost, perhaps quite, deserving of being denominated a branch of mechanical engineering. Our wealth in machinery and mechanism has come to be almost inconceivably great, and every piece of every however complicated mechanism is an expression, and a perpetuating memorial, of the cumbersome and costly miscellany which we have been accustomed to call a "system," the British "system" of weights and measures. Every minutest part of all this immense accumulation of machinery is an obstacle in the path of reform; every dollar of capital invested in the construction and in the employment of this apparatus, and the vastly more still to be built on that unsystematic "system," will be more or less an obstacle to change. Time and patience and steady persistence, without unreasonable aggressiveness, and reinforced by the natural tendency through moral and social gravitation towards improvement, efficiency and economy, will gradually remove all serious obstacles and, thenceforward, the advance will be rapid and smooth and fruitful of good. The English-speaking nations will not always lag behind in this, any more than in any other, direction of progress. They have usually

set the pace and may be fairly relied upon to maintain their standing hereafter.

Our work to-day is that of opening the way, of smoothing the road, of removing all meaningless obstacles and of teaching the captains and the pilots of industry their opportunities and their inducements to follow the paths thus made clear for them. Above all, we are to help make the metric system familiar to every child and youth in the land, and so familiar that it shall serve their purposes every hour in the day and better than the older and cruder "system" and its barbarous nomenclature. This being done, we may confidently leave the rest to time and the coming generation.

R. H. THURSTON.

SIBLEY COLLEGE, CORNELL UNIVERSITY,

February 17, 1902.

To the Secretary :

In accordance with request contained in yours of February 15th, I take this opportunity to make a few comments upon the subject to be considered before the meeting to be held this evening at Franklin Institute, namely, the adoption of the French metric system, primarily in the workshops connected with the different departments of the Government.

My views in regard to the matter have been abundantly expressed in the report of the majority committee to the Franklin Institute in 1876, also in my paper in regard to the Metric System in the Workshops, read before the Society of Mechanical Engineers, November 4, 1880, and other papers, and I see no reason to change my views as therein expressed. I have always been a strong advocate of the legalization of the metric system conjointly with our own. I have also persistently advocated the standardization of commercial material in harmony with the shop sizes in common use, all of which depend upon the inch as a unit.

The first question asked by the sub-committee of the Franklin Institute in their paper dated January 17, 1902, assumes the desirability of an international standard, namely, "Can we expect nations using the metric system to abandon that and adopt our system?" and I note that this is replied to in the negative.

In this connection I desire to call the attention of the members of the Institute to an interview I had in 1884 in England with Sir Joseph Whitworth, who, as you are aware, was noted for his improvements in the design of machine tools and the preparation of standard gauges, etc. (He at that time was in feeble health, and in point of fact was called from this life a short time afterward.) He raised this very question of the futility of asking foreign nations to adopt the standard of England

even with improvements as to the simplification of the units of measurement and weight, but he urged that I should use my influence to have the United States in the first place adopt the meter of *40 inches* in place of that now represented by a rod of platinum in the archives at Paris, measuring 39.371, approximately. This change would add only $\frac{1}{8}$ of an inch to the length of the French meter, and this would appear less in its subdivision, but it would result in an exact correlation between the English unit and its multiple and the metric system. As the comparison now exists, we have the anomaly of assuming 25.3995 millimeters to be equal to 1 inch, while if the change suggested by Whitworth were made, our unit would be 25 millimeters exactly; 100 millimeters (1 decimeter) would be 4 inches exactly; 300 millimeters would equal 1 foot, and 900 millimeters would be 1 yard. The difference of weight that would result from the cubing of these dimensions, or any portion of them, and their contents in the weight of distilled water at a certain temperature, would be insignificant. Already by Act of Congress it has been determined that for postoffice uses, 15 grams French weight shall be taken as equivalent to $\frac{1}{2}$ ounce, although the weight of 15 grams is slightly more than the weight of the $\frac{1}{2}$ ounce of the postoffice measurement.

Should the United States adopt a meter of 40 inches, all the standard dimensions of material used in the mechanic arts, as I have said, would be commensurate with our inch unit, and in harmony with our present metrological system.

I present this matter for the earnest consideration of the members of the Franklin Institute, for the reason that, while it is not reasonable to expect the French people and others to give up a so-called logical system of metrology, if the United States should adopt a metrical system with a 40-inch meter as the primary unit, the Empire of Great Britain, now representing three-fifths of our commercial interests, might adopt the same, and it seems reasonable to suppose that other nations would find it to their interest and advantage to fall into line.

In the second question of the circular referred to, the French metric system is claimed as advantageous in computation, owing to its harmony between weights and lineal measurements, which it is claimed can be borne in mind without effort. It would be interesting to know how many of the members who signed this report can repeat off-hand the system in all its details without error. I have closely observed the use of the French metric system both here and abroad, and note that the knowledge of each user covers only what relates to his own particular business and goes no further. A tailor in France or Germany or any other country where the French metric system is legalized has a tape-measure divided into centimeters and half centimeters, precisely as a tailor in America has a tape-measure divided into inches, halves and quarters. The finest measurement they have occasion to use is respectively $\frac{1}{4}$

of an inch in America, and 5 millimeters or approximately $\frac{1}{5}$ of an inch in France or Germany.

The division of material bought and sold by weight into halves and quarters is natural to the human mind. Its division into fifths or tenths is not conceivable. What is possible in money is not practicable in the market. Half of the kilogram, nearly equivalent to the pound, had to be legalized in France and Germany, and this again is subdivided into quarters and not into ten parts in such materials as meat and butter.

As to memorizing such a system, it is, I fear, more easily forgotten than acquired, as has been proved time and again by questioning those who are compelled to use it. The difficulty with English-speaking nations is that there is no correlation between the metric units and the inch, foot, yard or pound, but if we make the meter 40 inches long this difficulty disappears at once.

Without attempting to go further into the discussion of this subject, I would say that if the Institute desires to make any recommendations looking toward a change in our standards of measurement, I deem it advisable to call the attention of its members to Sir Joseph Whitworth's suggestion, which in my judgment is the simplest and wisest solution of the problem that has been presented.

I remain, yours truly,

COLEMAN SELLERS.

PHILADELPHIA, February 19, 1902.

To the Secretary of the Franklin Institute :

The commotion caused by the disturbance of established customs has been compared by Dr. Holmes with that which follows the overturning of a large flat stone which has long lain in the field. The good Doctor well describes the panic of its conservative population upon being deluged with the unaccustomed sunshine.

In the days of our forefathers such a disturbance accompanied the attempt to substitute the dollar and the cent for the pound sterling and its cumbrous subdivisions.

In our own days it took a mighty effort to convince our manufacturers that the blue-print was worthy of their attention ; and now the effort to substitute the meter and the centimeter for the yard, the foot and the inch, the cubic meter and centimeter for the cubic yard, foot and inch, and the various gallons, quarts, pints, bushels, pecks and what-not, and the kilogram and gram for the numerous tons, hundredweights, quarters, pounds, ounces, pennyweights, scruples and drachms, is giving rise to discussions like the present one—discussions upon which our posterity will assuredly look back with compassionate wonder.

That either of these reforms, instead of being immediately hailed

with delight and accepted in all its fullness, should have had to fight its way upward through dense overlying strata of stolid opposition, is a fine illustration of human conservatism, which includes an adherence to the existing order, in any given case, not for its merits, but simply because it is old; an adherence due to that mental inertia which makes us rather bear those ills we have than go to the trouble of thinking about anything in particular, and which yet, paradoxically, induces its votaries to take infinite pains and exhibit remarkable ingenuity in showing why any particular improvement should not be adopted.

But even that peculiarly aggravated phase of conservatism which prefers the British to the American coinage and the British to the civilized metrology, weakens before the all-subduing influence of time; and now, more than a third of a century since the use of the metric system was made lawful throughout the United States, the opposition to it is perceptibly weakening.

Even the manufacturer, who has so long been insisting that the introduction of the metric system meant his ruin, now admits that, when a large foreign order depends upon doing work in the metric system, that system is found not to be an insuperable barrier after all, and the order is taken.

To argue the superiority of the metric over what we may well blush to admit is still the British and the American system, would be a reflection upon the intelligence of the members of the Institute. In the language of the Editor of London *Engineering*, "the time has gone past when it was necessary to furnish arguments as to the advantages of the metric system over our own confused methods."

To my mind, the only serious reason for hesitation in pushing the adoption of the metric system, is that which, at first sight, appears to be its chief merit, viz. : its decimal basis.

The number 10 came to us as a basis of notation through our having each 10 fingers (including thumbs). Its unfitness for the purpose becomes manifest whenever we have occasion to think of the half of a quarter dollar and realize that this half is $12\frac{1}{2}$ cents, bringing us at once into inconvenient fractions. As my good friend, Mr. Benjamin Smith Lyman, says, in his paper entitled "Against Adopting the Metric System:" "If our early predecessors, in learning to reckon, had but omitted to count their thumbs, * * * they would have saved the world a vast deal of labor, and would almost have abolished the use of vulgar fractions."

Undoubtedly, some future generation will find itself using 8 or 12 or 16, instead of 10, as a base, just as our generation finds itself using the Arabic instead of the ancient Roman numerals. Therefore we must regard the metric system, not as a finality, but simply as a temporary expedient for the public welfare.

At first sight it might appear that the general use of the metric system, with its decimal base, would tend to perpetuate the decimal system, and to render more difficult the inevitable transition from it to the vastly preferable octonal or duodecimal system. If so, we might properly question the propriety of sacrificing the future for the present gain by adopting the metric system.

But, in the first place, the abandonment of the decimal base is so radical a step that we can hardly hope for its accomplishment during this or the next generation, and those generations might as well be delivered from the manifold inconveniences of the present alleged system.

In the second place, it seems altogether reasonable to hope that the metric system, by educating the popular mind up to the advantage of simplicity in matters of arithmetic, may rather help than hinder the ultimate substitution of a new basis of notation.

But, granted that there is no question as to the desirability of the speedy general adoption of the metric system, we may still ask whether the Franklin Institute, by taking the action now proposed, will help or hinder that consummation.

Certain experience of my own, in the use of argument based upon fact, as a means of bringing about the adoption of another sort of meter, has led me to question the efficiency of that method of obtaining popular approval of a measure smacking of innovation; and I have been ready to say, in my haste, that the speediest way to bring about the reform of an abuse is to keep quiet and let the abuse make itself intolerable. Until it does so, until the public really wakes up to the nuisance, argument against it only wearies those who do not keenly feel its burdens, and awakens the resentment of those who have some interest, if only the interest of conservatism, in maintaining it.

In all such movements, however, there comes a time when an organization like the Franklin Institute, universally respected as an authority (though coolly left without the support necessary for a decent existence), is looked to for its voice in the matter, and should feel that it owes it to the unappreciative public to utter that voice in no uncertain tones; and later there comes a time when the community, at last aroused, asks of the authority, "What! Slumbering still?"

It is now a quarter of a century since the Franklin Institute, by the narrow majority of 41 to 39, adopted a report opposing a proposition looking to the extended use of the metric system. At that time the Institute might have endorsed the metric system for *the system's* sake; but the time has now come when she *had better* endorse it for *her own* sake. She cannot afford to neglect the present opportunity of reversing her action of 1876.

JOHN C. TRAUTWINE, JR.

PHILADELPHIA, February 19, 1902.

To the Secretary of the Franklin Institute.

SIR :—I beg to offer as a contribution to the discussion of the metric system the following abstract of an argument of mine on the same subject before the Engineers' Club of Philadelphia, in 1895, together with a few additional remarks :

ABSTRACT OF ARGUMENT BEFORE THE ENGINEERS' CLUB IN 1895.—The arguments urged for the metric system are its convenience, either in use or in computation, and its ideal beauty.

The meter has no particular convenience in use, and is not especially fit to be a base of geographical measures or terrestrial arcs, since it is not even a simple subdivision of a meridian; and, though it were, the decimal subdivision of circles has never yet been found generally convenient. The length is passably good for cloth measuring, but for other use is either too long or too short a unit. To carpenters and smiths always in all countries the foot has been found the convenient unit; to sailors and miners, the fathom; and to machinists, the inch. The foot or two-foot rule readily folds into convenient subdivisions; the meter does not. Coleman Sellers, a highly competent authority of great experience, both with the metric and the common system, has shown that the inch is a far more convenient unit for machinists than any metric measure is; and that a change from the inch would cost them millions of dollars.

Convenience in computation is claimed for the metric system on account of correspondence with the ordinary decimal arithmetic. But the inconvenience of our common system is much exaggerated, and, in fact, causes difficulty only to the smallest children. The metric system, owing to the greater number of digits required, often makes the multiplication of dimensions together harder than with our measure. With our decimal money, in use for more than a century, mercantile men find it convenient to use halves, quarters, eighths and sixteenths, as every market report shows. Professional men that need frequent computations sometimes divide their unit decimally, as the surveyor his foot or chain, the machinist his inch, the chemist his weights, but the number of such men is probably not one in a thousand of the whole population. The number of men in commerce that would profit by increased ease of such computations is also comparatively small. Besides, our commerce with British countries is much more than with all others put together, and always will be, because one-third of the human race and one-fourth of the land of the world are under British and United States rule. Some countries have found profit in adopting the metric system because they had previously many different provincial systems, and uniformity is clearly a gain; but any uniform system would give that benefit. A radical change of system would require for many years frequent recomputation of old measures, both those of deeds and those of the Government

surveys, and in town-surveying for building purposes. In manufactures, too, many new patterns, tools and other appliances would have to be made, with great disarrangement of the present complicated, widespread system of interchangeable parts, shop sizes and merchant sizes, at a cost of many millions of dollars.

As for ideal beauty, the meter is merely a certain French bar of metal, not really a simple subdivision of any meridian; and any meridian that might be selected would be a local, national, political standard. The only beauty of the metric system, then, is its agreement with the common decimal arithmetical notation, a notation that is itself far from ideally beautiful, and that may some day be replaced by a better one. An eightfold notation would agree with the natural, most convenient method of subdivision by successive halving, and would almost entirely do away with vulgar fractions, and might be made easy of adoption by reforming our numeration with a dozen new words so simple that they could be learned in two minutes. Our present measures—the foot, hog-head, bushel, gallon, pint, pound, and many others—would harmonize admirably with such an eightfold notation, and with slight changes could be made to correspond exactly, if it should be thought desirable. The foot itself might be derived from twenty-seven times successively halving the earth's equator, the only standard the earth can give that is not local, and that can have a simple relation to simple subdivisions of the earth's surface. Such a foot would be only $\frac{1}{18}$ of an inch shorter than the average of the thirty-two principal European ante-metric feet, and less than $\frac{1}{4}$ of an inch shorter than our American and English foot.

It is clear, then, that the unquestionably difficult adoption of the metric system would not only occasion serious permanent inconvenience to much the greater part of our population without the justification of any ideal beauty, but would even be an obstacle to perfecting with slight and easy changes our present essentially far better system.

ADDITIONAL REMARKS.—To the preceding brief summary of my views, as expressed before the Engineers' Club, in 1895, I wish to add the following comments:

There are certain somewhat prevalent misconceptions as to the best standard and unit of measure, the best subdivision of the unit and a compulsory change to another system.

The primary standard, or the unchanging object which can be referred to for the verification of measures in use, is, of course, not necessarily the same as the unit of those measures. The British took for a standard the pendulum beating seconds at London, of which the yard and the foot are definite parts. The French, more than 100 years ago, generously aiming at yet greater universality and freedom from any local, national or political taint, but overestimating their knowledge and skill, undertook to use no less far-fetched and difficult a natural primary standard than a meridian of the earth; unaware that no two meridians

were of equal length, and arriving at a somewhat erroneous measurement of the French meridian selected. It has, however, been conceded, that, rather than refer again with such enormous pains to the natural primary standard, it is better to continue to use a secondary standard, the metallic meter so erroneously prepared. The meter, therefore, has been stripped of the only ideal beauty it was ever supposed to have. Moreover, it does not have even the practical advantage of producing measures in approximate agreement with commonly used arcs of the earth's surface; for repeated strenuous efforts have never been able to bring the decimal subdivision of the quadrant into general use. The metric standard, then, is, after all, merely a French piece of metal, subject to the vicissitudes of objects treasured in some particular country and place.

Units appear at times to be confounded with standards. At any rate, some admirers of the French system, with shallow wit and without looking beneath the merest surface of things, deride the humble origin of our ancient measures, taking them to be not mythically but really based upon the barleycorn and the human foot as standards. Those jokers must be seriously shocked to think that our early ancestors should not have used micrometers to gage the size of their fishhooks, arrowheads, bows, oars and canoes. Obviously, it was in their days not only natural, but the wisest possible plan to take the commonest things for units of length, especially some dimension of the ever handy human body, the finger, the thumb, the hand, the span, the foot, the cubit, the yard, the pace and the fathom. Of them all, the foot was, in the progress of enlightenment, and in all countries from the far East to the far West, found to be the most suitable unit of length for ordinary measures; though a decidedly longer unit, like the yard or fathom or even a longer one, was convenient for very long objects, such as cloth, or ropes, or land; and a shorter unit, like the inch, for small or nicely fitting objects, such as the parts of machinery. No inconvenience whatever arises from the co-existence of several such units; but in the comparatively rare cases of wishing to convert from one to another, it is desirable that their ratios should be somewhat simple, as in the conversion from feet to yards or fathoms.

The selection of a unit of measures should be guided by its convenience to the greatest number who use them most; not merely its convenience to the comparatively small number of chemists, electricians, geodesists or other scholars who may consider their computations to be facilitated by one or the other system, and that everybody else must be benefited in like manner, or to the comparatively few exporters of merchandise to Latin countries; but by the convenience of the unit in its almost infinitely more frequent use by the vastly more numerous whole population, by the carpenter, the smith, the miner, the farmer, the mechanic and laborer of all kinds.

The subdivision of the unit is likewise a matter of convenience: for most men and for the most frequent reckoning, which is in the head, successive division by two or three is most convenient; but for chemists, electricians, surveyors and those who have to reckon closely, with pencil on paper, a decimal subdivision is commonly found most convenient. There is, however, no reason whatever why this little convenience of a comparatively small number should be made the occasion of putting an immensely greater number to inconvenience. Topographers in leveling find the decimal subdivision of the foot convenient, but do not require others to imitate them. Land surveyors have for 250 years used a special unit and a decimal subdivision of it, without demanding that the whole community should conform to their practice.

Decimal subdivision may facilitate computation on paper, especially in adding up many digits, but reckoning in the head is much more easily effected with a subdivision by halves or thirds. That is clearly the reason why such fractions are in constant use in the stock market, even with our much vaunted decimal currency established more than a century ago. In a multitude of cases, too, it is easier to make a computation with those easy fractions than to undertake it with the more cumbersome tenths, hundredths and thousandths. Plainly, the mental computations are by far more frequent than ciphering, and would be still more so were we not somewhat tied down to the pencil by the decimal system, as the Chinaman is to his abacus.

In sum, our present system has a more convenient primary standard of reference, more suitable units, and, on the whole, a more satisfactory method of subdivision, and is, therefore, both logically and practically superior to the French system. For men who are without those advantages, the results of many ages of experience, to urge the abandonment of such superiority is like the recommendation of the tailless fox that all his race should remove their tails also.

Anything like compulsion to adopt the metric system of weights and measures would be gross injustice, forcing downright inconvenience and expense upon much the greater part of the community, and making us perhaps seem to play the part of enthusiastic theorizers carried away with a beauty that is, in this case, really only skin-deep, but that nevertheless might well be attractive to the æsthetic disposition, and especially so to the young, the half-taught and the inexperienced, not yet reduced to the strictly practical. There may be no harm in permitting, without compulsion, the use of the sufficiently precise foreign system; and if ever its use should unexpectedly prove itself in practice to be satisfactory to anything like a majority of the public, it will be time enough to consider the discontinuance of the present equally precise and yet more soundly rational system.

BENJ. SMITH LYMAN.

PHILADELPHIA, June 2, 1902.

[*To be continued.*]

Section of Photography and Microscopy.

Stated Meeting, held Thursday, May 1, 1902.

A Method of Measuring Objects in the Microscope.

BY FREDERIC E. IVES,
Member of the Institute.

In Carpenter-Dallinger on the Microscope (seventh edition, p. 226), the following is given as the "simplest" method of measuring objects in the microscope:

"Project the magnified image of the object by any of the methods described under 'camera lucida and drawing.' If we carefully trace an outline of the image, and then, without disturbing any of the arrangements, remove the object from the stage and replace it with a 'stage micrometer,' which is simply a thin slip of glass ruled to any desired scale, such as tenths, hundredths, thousandths of an inch and upwards. Trace now the projected image of this upon the same paper, and the means are at once before us of making a comparison between the object and a known scale, both being magnified to the same extent. . . . In favor of the above method . . . it will be noted [1] that no extra apparatus is required, [2] that it is extremely simple, and [3] that it is accurate."

A quite expensive accessory, the screw micrometer eyepiece, is then referred to as the most efficient piece of apparatus for this purpose, and the use of a simple form of eyepiece micrometer, which is the most usual practice, is described as being somewhat less accurate than either of the other methods.

Even the use of an eyepiece micrometer involves a separate determination of its values for every objective and for some particular tube-length for each objective, and with that particular eyepiece which contains the scale. Any one who employs a considerable variety of objectives will require a rather formidable reference table, must work with the tube-length indicated in the table, and must use a particular eyepiece, in order to get a measurement.

It goes without saying, that a method which would give a direct reading, which would not be affected by change of objective, eyepiece or tube-length, would be more convenient and generally more desirable than the methods above described.

Such a method which I have realized consists in projecting the image of an illuminated scale in the plane of the object by means of the substage condenser. An efficient apparatus can be made for a few cents, and after it has once been adjusted by the aid of a stage micrometer, it can be brought into service at a moment's notice whenever wanted.

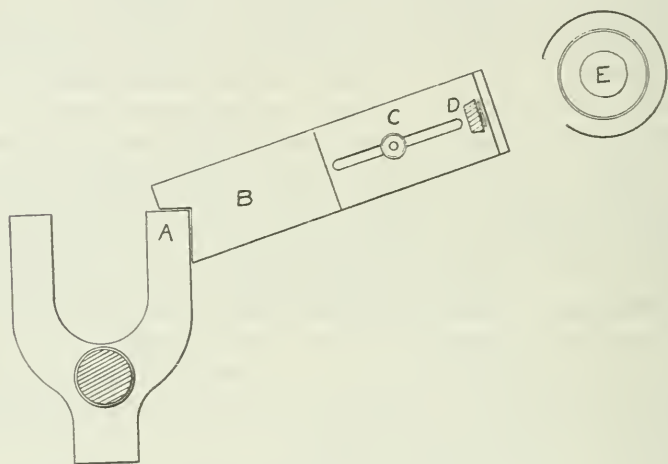


FIG. 1.

This apparatus is best made with a fixed adjustment for a particular microscope stand, and for illumination from a particular direction. I shall therefore describe the device which I am using with a Bausch & Lomb "BB" stand and a Welsbach light. Other forms of stand and other sources of illumination can readily be provided for.

In the diagram, *Fig. 1*, *A* is the base of the microscope, *B* a block of wood seven inches long (notched to fit against the microscope base and project in a particular direction, as shown), *C* is a rider with set-screw and a post and spring-clamp *D*, to hold a jeweler's saw having sixty-four teeth to the inch. *E* is the Welsbach light, diffused by a ground-

glass chimney and shielded from the eyes by a hood open only on the side towards the microscope. The source of light being on a level with the microscope, the jeweler's saw is supported in a vertical plane, directly between the light and the microscope mirror, and in this position its image can be focussed in the field of the microscope by racking back the condenser just a trifle. The image of the saw-teeth constitutes the measuring scale, which can be given any desired value, within limits, by adjusting its distance from the microscope mirror and comparing the focussed image



FIG. 2.

with the scale on a stage micrometer. My adjustment makes each tooth equal to one-fiftieth of a millimeter on the stage micrometer.

Of course, an engraved scale, on glass or celluloid, can be substituted for the jeweler's saw, and the apparatus may be otherwise elaborated, as by making the scale revolvable and otherwise adjustable as to position and angle, but these are refinements which I do not at present require.

When the scale is not wanted the block is pushed aside and can be brought back into position in an instant.

It is evident that in order to insure strict accuracy the scale itself must be accurately divided and must occupy a

position at right angles to a line drawn from the center of the source of light to the center of the mirror; the distance must be constant, the surfaces of the mirror must be plane, and the condenser must be capable of projecting a sufficiently sharp and undistorted image. For such measurements as would be required with low and medium-power objectives, I have found an ordinary Abbe condenser efficient by closing up its iris to sharpen the image. An achromatic Abbe condenser used in the same way will define well enough to provide a readable $\frac{1}{100}$ -millimeter scale. With a better corrected achromatic condenser I have obtained a satisfactory $\frac{1}{200}$ -millimeter scale, and it seems probable that one of the newer types of aplanatic, achromatic or apochro-

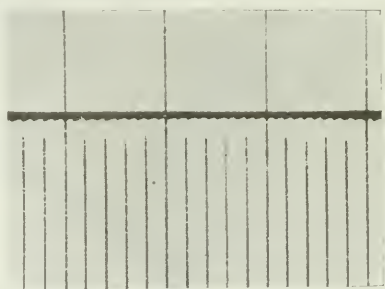


FIG. 3.

matic condensers, now regarded by some authorities as almost indispensable for really critical work with the microscope, would define a scale to measure with sufficient accuracy to $\frac{1}{1000}$ millimeter. The expensive and comparatively troublesome Filar micrometer will make still smaller and more accurate measurements, which, however, are very seldom required and are not provided for in the equipment of the great majority of microscopists.

Fig. 2 is a photograph of an image of both object and scale as seen in the field of the microscope, but with a coarser scale than I have described.

Fig. 3 is a photograph of a $\frac{1}{100}$ -millimeter projected scale in the field with a $\frac{1}{100}$ -millimeter stage micrometer.

Erratum.

Correct date of meeting of Electrical Section, at which Mr. C. J. Reed's paper on "Electro-chemical Polarization" was presented, to read November 21, 1901.

W. H. W.

Notes and Comments.

EXTRAORDINARY DEVELOPMENT AT THE "SOO."

Without question, one of the most active scenes of engineering development at the present time in the United States is the "Soo" district, at the point on St. Mary's River where Lake Superior empties into Lake Huron, and where two large industrial towns on the American and Canadian sides have already sprung up. At this point the river has a fall of about nineteen feet at the Rapids in a distance of 3,000 feet, developing at least 175,000 horse-power. Part of this energy, hitherto wasted, has already been utilized on the Canadian side, and at the present moment two other kindred enterprises are being pushed. While the development will be in sharp contrast to that at Niagara, owing to the slight head of water at the "Soo" as compared with an average of about 200 feet at the great cataract, the two enterprises compare in magnitude and each presents unique features. Data were recently given in these columns as to the new work at Niagara on the Canadian side, for which three of the largest generators in the world are being built. A contrast is presented by the plans for the "Soo," where for the new work now to be carried out, the Stanley Electric Manufacturing Company, of Pittsfield, Mass., has been awarded a contract for no fewer than 40 generators, etc., the impulse wheels to drive which are already in place. The building in which these machines will be installed is itself over a quarter of a mile long and three stories in height, and the power canal which will divert water from the Rapids to the wheels has also been dug and finished, 210 feet wide, 20 feet deep and 5 miles long. This development is on the American side of Sault Ste. Marie.

The amount of power to be developed will, it is stated, approximate 100,000 horse-power, and this extraordinary plant will unquestionably be by far the largest hydro electric equipment under one roof in the world. The current will be utilized by the Clergue syndicate, which is backed mainly by Philadelphia capital, for the rolling mills, pulp mills, electro-chemical works and other industries of the Consolidated Lake Superior Company and concerns of a similar character, while it is believed that a large part of the current will also be transmitted to Canada. The electrical contract is now being carried out and the apparatus will be installed forthwith. It is curious to think that the same water thus used so much higher up on the chain of lakes should again yield its energy at Niagara. The current generated will be three-phase, 30 cycles.—*Electrical World*.

THE CENSUS FIGURES FOR THE METALLURGICAL INDUSTRIES.

Although there have been some innovations in the iron and steel industry since the gathering of statistics for the census of 1900, and the returns therefore have lost some of the significance which they might have otherwise, the figures still are possessed of both intrinsic and relative value.

It is notable that the iron and steel industry is given second place in the list of selected industries prepared by the Bureau of Manufactures, textile industries taking first place, with the total value of the products placed at \$966,924,835. If the metal industries are grouped together, however, as are the textile manufactures, the metal products take precedence, the value of the iron and steel, lead, copper and zinc manufactures aggregating \$1,194,545,506. And the metal industries, too, seem to be the more profitable, as the aggregate capital invested, as given by Mr. North, the Chief Statistician, is \$719,395,848, against \$1,066,032,937 invested in the manufacture of textiles.

This is a matter of no great concern, however, and among separate industries iron and steel is far in the lead, giving evidence of the greatest vitality. Not only is the value of the product greater than that of any other industry, but a larger amount of money is distributed to the wage-earner and, with the exception of the woolen, cotton and lumber interests, employment is given to a larger number of workers; indeed, in the engagement of skilled labor the iron and steel industry stands pre-eminent. The total number of men employed was 226,161, who received \$122,710,193 in wages, the rolling mills and steel works leading with 183,023 men, who earned \$102,238,692, while the blast furnaces employed 39,241 men, who were paid \$18,484,400.

In 1900 there were 725 establishments—including 57 making tin andterne plates—engaged in the iron and steel industry, an increase of six plants, or a gain of 0.8 per cent., since 1890. It is a matter of interest that there were 438 active rolling mills and steel plants in 1900—a gain of 43 since 1890—while there were only 223 blast furnaces blowing, against 304 active stacks in 1890. The number of forges and bloomerics was reduced from 20 in 1890 to 7 in 1900.

The capital invested in the 725 active establishments in 1900 was \$580,041,710, employment being given to 226,161 workers, earning \$122,710,193, while the salaries paid to the 9,544 officers and clerks engaged amounted to \$12,028,811. The cost of the materials used for conversion was \$549,127,082; miscellaneous expenses were \$32,570,556, and the value of the manufactured products, as previously stated, was \$835,759,034. The latter is made up of \$596,588,034, the value of the manufactures from the rolling mills and steel works; \$206,756,557, the value of the output of the furnaces; \$31,892,011, the value of the tin and terne plate, and \$522,432, the value of the products from the forges and bloomerics.

In 1900 there were 117 plants engaged in the smelting and refining of metals, 39 in the smelting and refining of lead, 47 in copper and 31 in zinc. The total capital invested in the smelters and refineries was \$139,354,138, employing 1,121 officials and clerks, drawing salaries amounting to \$2,150,018, distributing \$15,937,626 to 24,504 wage-earners, expending \$279,655,350 for raw materials and turning out manufactured products valued at \$358,786,472.

—*Iron Age.*

Franklin Institute.

[*Proceedings of the Stated Meeting held Wednesday, June 18, 1902.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 18, 1902.

Vice-President WASHINGTON JONES in the chair.

Present, 60 members and visitors.

Additions to membership since last report, 5.

Dr. J. Merritt Matthews, of Philadelphia, presented an informal communication on "Viscose and Its Applications," illustrating the subject by the exhibition of numerous specimens. The speaker was accorded the thanks of the meeting.

Mr. J. Allen Heany described and exhibited in operation an improved Enclosed Arc Lamp of his invention.

Mr. E. D. Dorsey gave a brief account of the development of devices intended for addressing envelopes, wrappers, etc., for mailing and other purposes; and described and showed in operation an improved apparatus of this class, called the "Addressograph," for which special advantages were claimed.

The several subjects presented at the meeting were severally referred to the Committee on Science and the Arts for investigation and report.

Mr. W. N. Jennings showed a number of lantern slides from photographs taken by him from the top of the Washington Monument.

Mr. John Carbutt followed with a series of slides from photographs of star clusters and nebulae, made by Professor Ritchie, of Yerkes Observatory.

Action on certain pending amendments to the By-Laws of the Institute was deferred. Adjourned.

WM. H. WAHL, *Secretary*.

Committee on Science and the Arts.

(*Abstract of proceedings of the stated meeting held Wednesday, June 4, 1902.*)

MR. THOMAS P. CONARD in the chair.

The following reports were adopted:

(No. 2210.) *A Theory of Electricity*.—John Trewhella, Coatesville, Pa.

(An advisory report.)

(No. 2212.) *Rheostat*.—Charles Wirt, Philadelphia.

ABSTRACT.—This apparatus is the subject of letters-patent of the United States, No. 633,172, September 19, 1899, granted to applicant.

The special novelty of the apparatus resides in the use of a continuous strip of resistance material without joints. This strip is a ribbon of metallic alloy coated on one side with an insulating material (such as flake mica), held in place by shellac, so that when the strip is wound in a flat coil there is a layer of insulation between each layer of conducting material. In making these strips into a rheostat they are wound upon a mandrel of flat oval section, a certain number of turns being wound one on top of the other, when a

slight sideways shifting allows another series of turns to be wound upon the mandrel without breaking the continuity of the strip itself.

When a sufficient number of these flat coils have been wound upon the mandrel they are slid off, and the coils are arranged in a circle upon a plate which forms the back of the instrument. The necessary contact strips are then placed in position, one on the face of each coil, and extending the full length and width of same. The front plate, with the necessary insulation, etc., is placed upon these, and the whole subjected to heavy compression, while a steel ring is spun over the outer edges of the plates, making the compression permanent and leaving the instrument ready for the placing of the center spindle and contact arm.

The advantages claimed for these rheostats are: small size combined with large capacity; a large subdivision of the resistance without undue expense; small liability to damage owing to the absence of all soldered joints; and long life for the same reason.

The investigating body subjected one of these rheostats, suitable for a 5-horsepower motor, to the severe test of a large number of heatings and coolings, which were estimated to be the equivalent of two years' service.

On dismantling the instrument it was found, at the conclusion of the tests, that none of the contact strips had been moved or shifted, nor had the resistance strip apparently sustained any damage. The insulation between the layers of the coils seemed in perfect condition, and the metallic contacts between the strip and contact plates showed no deterioration except where the cooling water (used in the tests) had penetrated.

The report concludes that the claims made for the Wirt rheostat are sustained. The Scott award is recommended to the inventor. [*Sub-Committee.*—T. Carpenter Smith, Chairman; Clayton W. Pike.]

(No. 2228.) *Photomicrographic Device*.—Frederic E. Ives, Philadelphia.

ABSTRACT.—The object of this device is to improve upon existing appliances for photographing the visible field of a microscope or other optical instrument, and especially to serve the convenience of the operator by permitting the instrument, when in use, to remain undisturbed while its field is being photographed, and also to determine with greater facility the ratio of magnitude between the visible field and its photographed reproduction.

[For a detailed description of the apparatus, with illustrations, the reader is referred to this JOURNAL, Vol. CLIII, 371, May, 1902, ART., "A Photomicrographic Device," Ives.]

The investigators say in their report that the novelty of this apparatus consists in the simplicity of the means by which the camera and the microscope may be brought into combination or disengaged, and the gist of the invention lies in the ingenuity with which the simplicity of the apparatus is maintained, together with a thorough adaptability for its purpose.

"In recognition of the value of this microscopic camera in materially facilitating the production of photographs with the microscope," the award of the Edward Longstreth Medal of Merit is made to the inventor. [*Sub-Committee.*—Louis E. Levy, Chairman; H. R. Heyl, Samuel Sartain.]

The following reports passed first reading:

(No. 2174.) *Cipher-Code System*.—Willis J. Roussell, New Orleans, La.

(No. 2221.) *Electric Elevator for Private Residences*.—Otis Elevator Company, New York.

WM. H. WAHL, *Secretary*.

JOURNAL

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VOL. CLIV, No. 2. 77TH YEAR. AUGUST, 1902

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

Agriculture in Its Relations to Bacteria and Other Ferments.

BY H. W. WILEY,*

Chief of the Bureau of Chemistry, U. S. Department of Agriculture—
Honorary Member of the Franklin Institute.

It is rather difficult to come before a city audience with a purely agricultural subject. A few years ago it was difficult to address farmers on such a subject as I have to take up to-night. They knew nothing of how plant-foods were prepared, and especially of the relation of ferments to agricultural industries. Even at the present time we are prone to look upon bacteria and other ferments as the enemies of mankind; yet if the facts were well known nearly all the organisms which we look upon as our enemies would be regarded as our best friends.

Especially do the processes of fermentation lie at the very foundation of plant and animal life. Without fermentation, the organic food which contains the elements of

*A lecture delivered before the Franklin Institute, Friday evening, November 1, 1901.

plant-nutrition would never be reduced to a condition in which the plant could assimilate it. Without fermentation, the great œnological industries of wine-making, beer-making and cider-making would be impossible. Butter and cheese would have no flavor, and, in general, the world would become stagnant and dead. It is true that there are a few pathogenic germs which produce disaster and even death, but if we could have our desires and bring death to all germ-life, we would destroy agriculture and thus the human race.

Agriculture is the basic industry, because without it all others would be impossible. The world might do without steel, without steam and without sterilization, but it could not exist without bread and meat. To paralyze the agricultural industries of the world for a single year would bring famine and death to almost the whole human race. In other words, the stores of foods and other agricultural products necessary to life which are carried over from one year's end to another would not be sufficient to carry the human race through a single season of agricultural disaster. Hence, even those living in cities are beginning to understand the importance of agriculture and to know that while it is the oldest art it is almost the newest science.

What I wish to take up principally to-night are those ferments of a bacterial nature, which, living in the soil and in symbiosis with certain plants, are capable of preparing organic food that plants may eat it. Formerly, the soil was regarded as mineral matter, simply decayed rocks mixed with dead organic material. Now we know that the soil is a living organism whose life is as important as that of the animal or the plant itself. If the soil be killed it is absolutely sterile. In other words, if the living organisms which make soil fertile are destroyed, the soil is incapable of producing a crop. Plants as a rule eat only mineral food, such as phosphoric acid, potash and nitric acid, but animals, usually, eat only organic foods, such as fats, sugars and protein matter. Plants cannot be fertilized with fats or sugars or with protein matter, but the nitrogen which the protein contains is the most important element of plant-food

and it is only through bacterial or fermentative action that this nitrogen is converted into nitric acid, in which form alone the plant can consume it.

Agricultural chemistry has developed what is now a well-known fact, that plants are pre eminently eaters of mineral matters. Through the plant the mineral matter is changed in its structure, passing into organic forms of combination in which alone food can nourish animal life. Nitrogen is one of the chief elements of plant-food, but in the inert state in which it exists in the atmosphere it is of no digestive value whatever. A plant will speedily starve and die for lack of nitrogen in an atmosphere four-fifths of which are composed of that gas. In like manner a plant would wither and die if fed unlimited quantities of nitrogen in an organic state of combination, or even as ammonia, in any of its compounds. With the exception of a few unimportant cases, the plant can only eat nitrogen when it is presented in the form of nitric acid or of a nitrate of some kind, such, for instance, as the nitrate of soda.

The term nitrification, therefore, is applied generally to the whole process, by means of which free nitrogen or any organic or inorganic compound of nitrogen reaches the state of nitric acid.

This definition shows at once that the process includes two general types :

(1) The conversion of nitrogen, existing free or in inorganic compounds, into nitric acid.

(2) The conversion of organic nitrogen into nitric acid.

The decay of organic matter containing nitrogen is due to the activity of certain living organisms of a bacterial nature, through whose vital functions the destruction of the organic matter is accomplished. The first tendency in the destruction of organic matter is its resolution into other compounds less complex, and the final tendency is the resolution of organic compounds into the original elements.

Since we are concerned at the present time only with nitrogen, we find that in the process of decay the nitrogen may exist in a large number of different combinations and, when the process is carried to its ultimate end, free nitrogen

may result. For the particular purpose of this paper, we may say that the nitrifying process in organic matter is accomplished in three great stages, namely:

(1) The conversion of the organic compounds into ammonia or compounds of ammonia.

(2) The conversion of ammonia into nitrous acid or compounds of nitrous acid.

(3) The conversion of the nitrous acid into nitric acid or compounds of nitric acid.

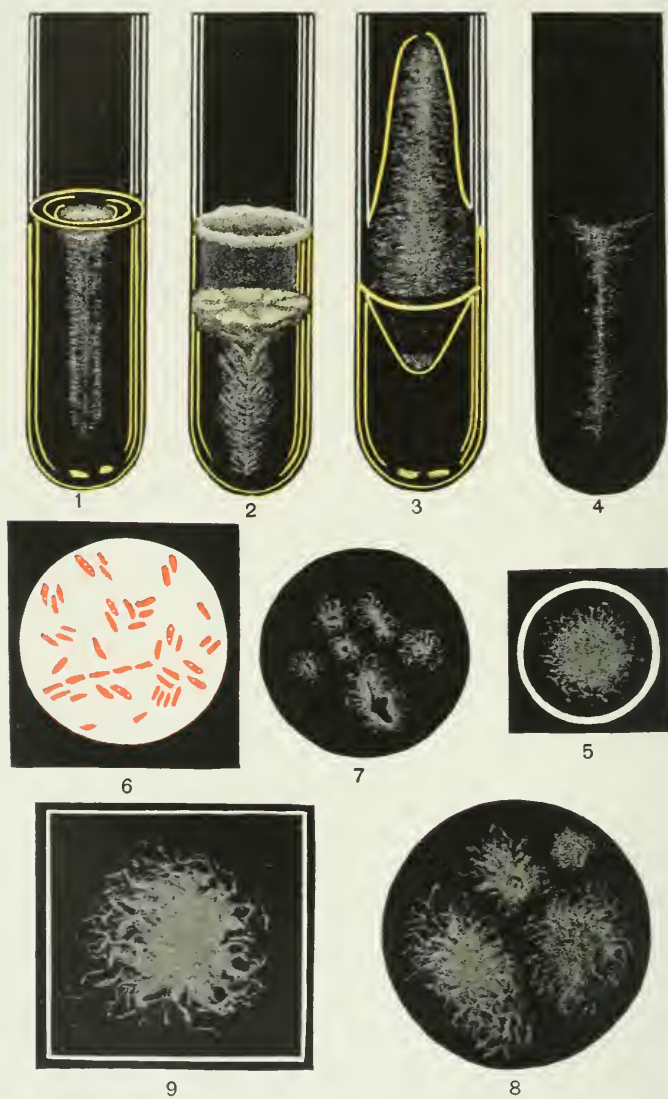
Each of these processes is accomplished by a distinct species of organisms, each species being suited only to its own work and being incapable of accomplishing the work of others. Thus it happens that if only the organisms capable of producing ammonia be present, the process of decomposition stops at the first step; and if only those capable of producing ammonia and nitrous acid be present, it stops at the second step; whereas, if all three families of organisms be present, the process is completed with the formation of nitric acid.

If we go further and produce free nitrogen, the process is no longer properly called nitrification but denitrification.

It is evident, from the standpoint of agriculture, that the best results are accomplished when nitric acid is produced. The presence of denitrifying organisms, therefore, must be regarded as inimical to agricultural interests.

I will now show, by projections upon the screen, the organisms of the three classes which have been mentioned. (The lecturer projected upon the screen micro-photographs of the organisms producing the three types of nitrification mentioned.) The organisms producing ammonia are more numerous, while those forming nitrous and nitric acids are few in number, in fact only one well-defined species of each kind is known to exist. The nitrous organisms are much larger than the nitric organisms and these two are intimately related, but one is not capable of performing the functions of the other.

The most important of the organisms developing ammonia from organic matter is the *bacillus mycoides*. The colored plate representing the different stages of develop-



FIGS. 1 TO 9.—*Bacillus mycoides* and illustrations of its activity.
SIP. fecit.

ment and activity of the *bacillus mycoides* has been adopted from Volume X, the first part of "Bacteriological Diagnostik" by Lehmann, Table 4.

Fig. 1 represents the appearance of the gelatine culture in a test-tube on the fourth day, of a temperature of 22°.

Fig. 2 the same on the fourteenth day.

Fig. 3 represents the culture in agar-agar two days old.

Fig. 4, agar-agar culture, eight days.

Fig. 5 represents the upper surface of the culture on the eighth day.

Fig. 6 represents a pure culture of the *bacillus mycoides* stained.

Fig. 7 represents a culture on an agar plate at the end of the first day, natural size.

Fig. 8 represents the culture on an agar plate, four days old, natural size.

Fig. 9 represents a culture on a gelatine plate on the fourth day, natural size.

The following description of the *bacillus mycoides* is taken from Wiley's "Principles and Practice of Agricultural Analysis," Volume I, page 464:

"*Bacillus mycoides* is the most active of these organisms. It occurs constantly in surface soils and is present in the air and in natural waters. In decomposing albumin it produces a strong alkaline solution due to ammonium carbonate. Organic carbon, during this process, is converted chiefly into carbon dioxide, but small quantities of formic, propionic and butyric acids are also produced. Any organic sulphur which is present is converted into acid. No hydrogen or nitrogen is eliminated in a free state. While slight alkalinity is favorable to the development of this bacterium, yet it may be propagated in a feeble sulphuric acid solution when the acid is less than 1 per cent.

"The greatest activity of this organism is manifested at 30°. Below 5° and above 42° no ammonia is produced. The *bacillus* will not develop in an atmosphere of hydrogen or carbon dioxide, except in solutions of organic matter and nitrate. In addition to its action on egg albumin, it decomposes other proteid bodies as well as leucin, tyrosin, creatin

and asparagin. It, however, does not oxidize urea, nor does it develop in solutions of ammonia salts and nitrates, except as mentioned above. When soluble carbohydrates are present, acids are formed. It is concluded from these experiments that the final oxidation of organic nitrogenous matter is preceded by its conversion into ammonia carbonate."

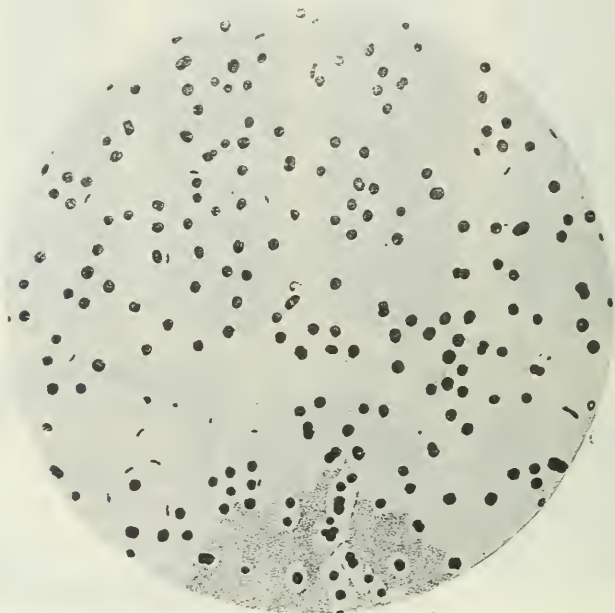


FIG. 10.—Nitrous ferment prepared by Winogradsky from soil from Cito.

CONVERSION OF AMMONIA INTO NITROUS ACID.

So far as is known, there is only one species of bacteria which has the power to convert ammonia into nitrous acid. This bacterium has been isolated independently both by Warrington and Winogradsky.

These bacteria are practically alike in all soils, but in some soils they seem to be more active than in others, so that it may be necessary to distinguish some minor differences in specific qualities.

The whole group of bacteria active in changing ammonia into nitric acid may be described as nitro-bacteria. The one

converting ammonia into nitrous acid is known as nitrosomonas, and the group converting nitrous into nitric acid is known as nitro-bactere.

The nitrous ferment is much larger and apparently more vigorous than the nitric ferment. The illustrations of the groups are taken from Wiley's "Principles and Practice of Agricultural Analysis," Volume I, facing page 480. They are due to Winogradsky.

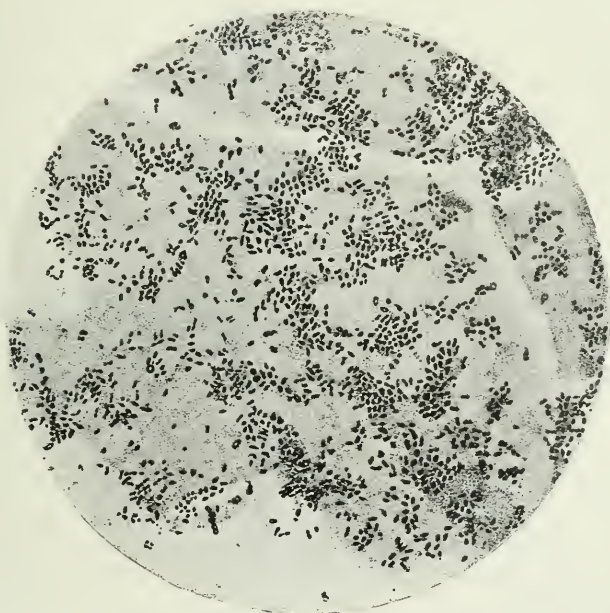


FIG. 11.—Nitric ferment prepared by Winogradsky from soil from Cito.

The second type of nitrification to which attention has been called is that process by means of which the atmospheric nitrogen is converted into forms suitable for plant-food. It is well known that combustion, electrical discharges and some natural forces are capable of converting a small quantity of nitrogen into nitric acid. The amount thus converted is not inconsiderable from an agricultural standpoint, and large quantities of nitrogenous plant-food annually reach the surface of the earth in rain-water.

More important to agriculture are the possibilities of the nitrifying organism acting directly upon atmospheric nitrogen. These organisms do not exist to a very large degree in a free state but are found in symbiotic union with a certain family of plants.

In so far as is definitely known, the leguminosae, that is, the family to which clover, peas, beans and similar plants

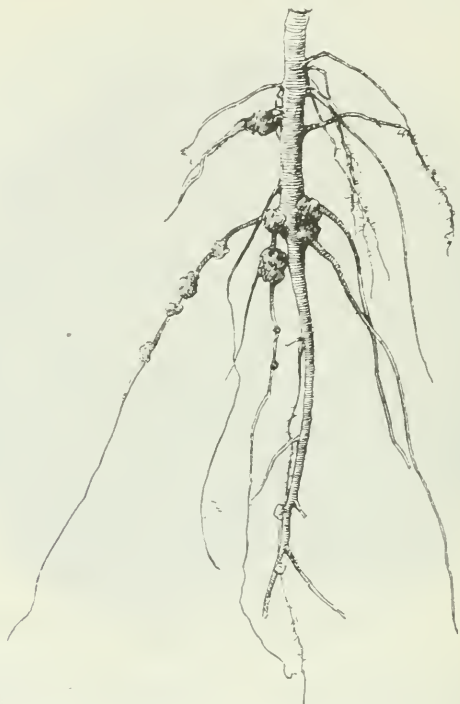


FIG. 12. Roots of Yellow Luzerne showing the nodules in which live the bacteria capable of oxydizing free nitrogen. *Drawn from Photograph by S. I. P.*

belong, are the only plants capable of supporting the parasitic life of these nitrifying bacteria. From time immemorial it had been noticed that such plants often had small nodules on their roots from the size of a shot to the size of a pea. These were formerly supposed to be evidences of a diseased condition. Some ten years ago it was discovered that these nodules were inhabited by bacteria which have

the faculty of converting free nitrogen into forms suitable for plant-nutrition. Thus, what was supposed to be the effect of a disease is found in fact to be a most useful form of bacteria.

Many attempts have been made to induce these bacteria to grow upon the rootlets of other plants, but so far without success. In the light of this knowledge we are able to explain the phenomenon which has long been known to exist, namely, that by the growth of clover, peas and beans, and by plowing this growth into the soil, the fertility of the soil can be increased. We see now that this increase of fertility is due to the fixation of atmospheric nitrogen, and thus there is offered to the scientific farmer a way of enriching his soil at the expense of the atmosphere itself.

A characteristic illustration of the attachment of these bacteria to the roots of a leguminous plant is shown in *Fig. 12.*

The discovery of the existence of these organisms has led to systematic cultures with a view to supplying them to soils which are deficient in them. The commercial name which is applied to these cultures ready for distribution is *nitragin*.

These cultures are supplied in small phials or bottles and are prepared by adding them to a mass of moist rich earth, which is frequently stirred to promote the multiplication of the organisms throughout the whole mass. When they have multiplied sufficiently, the mass of earth containing them is scattered over the fields in which it is desired to introduce the organisms. The organisms may also be suspended in water with which the seeds of the leguminosae are sprinkled, and thus the organisms are carried directly into the soil with the seed.

Experience has shown that these organisms developed on the rootlets of one kind of leguminosae are not well suited to the growth of other kinds. For instance, the organism developed on peas and beans do not do well with clover, and vice versa. Thus it is necessary to state upon the package the character of the group to which the *nitragin* is adapted.

Numerous experimental cultures have shown the utility of these organisms, but their application in field culture has not been so successful. The laws which govern the distribution and multiplication of these organisms in the field, and the best methods of attaching them directly to the rootlets of the plants, are not fully developed. There is every reason to believe, however, in view of all that has been accomplished, that the future will see a systematic and successful method of applying root bacteria in the development of all forms of leguminous plants.

Soil bacteria, which it is claimed are useful in general agriculture, have also been propagated by cultures, and likewise placed upon the market. One species of these bacteria is known as alinite. Alinite is claimed to be a germ through the activity of which free nitrogen enters into chemical combination in a form especially adapted to the nourishment of cereals. The process of manufacture is covered by patents. The product is a brownish yellow amorphous powder which is usually delivered in a sealed yellow glass tube accompanied with directions for its use.

[To be concluded.]

ARTIFICIAL ABRASIVES.

In the volume of the Mineral Resources of the United States, 1901, about to appear, Dr. Jos Hyde Pratt (U. S. Geological Survey) makes the following references to the production of artificial abrasives:

"The experiments in producing artificial abrasives that have been in progress during the last fifteen years have met with success, and there are now three artificial abrasives on the market—carborundum, crushed steel and artificial corundum. Carborundum is produced by the Carborundum Company at Niagara Falls, and in 1901 the total production of carborundum was 3,838,175 pounds, valued at from 8 to 10 cents per pound, as compared with 2,401,000 pounds in 1900. Carborundum is now used to a certain extent as a general abrasive. Crushed steel is used in the stone-cutting trade, particularly by the marble and granite cutters. The production of crushed steel by the Pittsburgh Crushed Steel Company in 1901, amounted to 690,000 pounds, being 10,000 pounds less than the production of 1900. A new industry has been started in the manufacture of artificial corundum. The Norton Emery Wheel Company has erected a plant at Niagara Falls for the manufacture of artificial corundum, and already two or three carloads of the material have been manufactured and made into wheels, etc., which are reported as giving good satisfaction."

Equilibrium of Iron-Carbon Systems.*

BY G. CHARPY AND L. GRENET.

M. Bakhuis Roozeboom gave in 1900† an interpretation of known facts relative to the constitution of metals formed of iron and carbon, which is unexceptionable from a theoretical point of view, but upon which some points remain doubtful on account of insufficiency of exact experiment. In particular, the conditions in which M. Roozeboom admits that carbon separates under the form of graphite in white-iron castings submitted to annealing have appeared to be contradictory to a certain number of facts previously observed in the manufacture of malleable-iron castings. Messrs. Le Chatelier and Stansfield have raised some objections on this point, and cited some experiments of Royston, Mannesman, etc., according to which the separation of graphite conforms to a diagram notably different from that adopted by M. Roozeboom. In these experiments, made on a practical point of view, account has not been taken of substances other than the carbon contained in the castings; notwithstanding, certain substances, silicon, manganese, etc., have an incontestable influence on the separation of graphite. One can believe then, as appears to be admitted by Mr. Hugh P. Tiemann, in a work recently published,‡ that the abundant separation of graphite observed by M. Royston was due to the presence of silicon in the castings employed.

We have made a large number of experiments on this point of view; we note, in particular, the results obtained

* Translated from *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, 31 Mars, 1902, by A. E. OUTERBRIDGE, JR.

† H. W. Backhuis Roozeboom. Iron and steel from the point of view of phases. *Bulletin de la Société d'Encouragement*, Novembre, 1900.

‡ Hugh P. Tiemann. The temperature limits for the separation of graphite from martensite in pure cast-iron. *The Metallographist*, October, 1901.

on five castings containing practically the same amount of total carbon, and in which the other elements exist in small quantities, except silicon, which is in variable proportions.

The following table gives the composition of the castings :

TABLE I.

	Carbon.	Silicon.	Manganese	Sulphur.	Phosphorus.
No. 1 . . .	3'60	0'07	0'03	0'01	traces
" 2 . . .	3'40	0'27	traces	0'02	0'02
" 3 . . .	3'25	0'80	traces	0 02	0'03
" 4 . . .	3'20	1 25	0'12	0 01	0'01
" 5 . . .	3'30	2 10	0'12	0 02	0 01

The castings had been poured into cold water and did not contain any appreciable quantity of graphite, except the last, where there was found 0'20 per cent.

Some fragments of these castings were subjected to annealing more or less prolonged at various temperatures; these temperatures were obtained either by continuous increase or by decreasing, after having attained a temperature more elevated; in each case the operation was terminated by quenching in cold water. In the specimens thus treated, we determined the total carbon and graphitic carbon, the difference giving the combined carbon.

The graphite was determined by the process indicated by Ledebur dissolving the metal in nitric acid of the density of 1'18 and burning in oxygen the insoluble residue remaining after boiling one hour.

It does not appear to us useless to specify that what we call graphite in this work, according to custom in metallurgical researches, is the residue of carbon insoluble in nitric acid. We determined in each case also the silicon.

From all these tests we can deduce the following results relative to the separation of graphitic carbon by annealing. We give, in each example, the percentages observed of graphite and of combined carbon, of which the sum total is not rigorously constant for each specimen. It is necessary, therefore, to take account of the values of both these figures



FIG. 1—White iron.

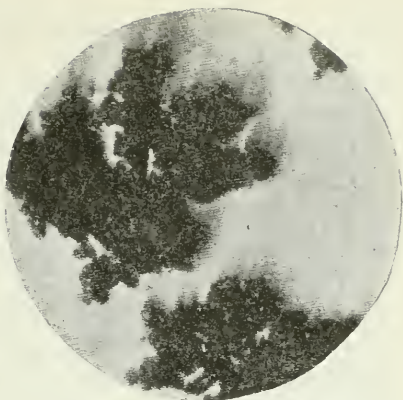


FIG. 2—Casting No. 2. Heated to 1000° (simply polished).

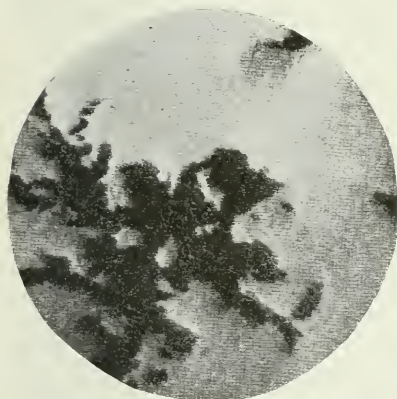


FIG. 3—Casting No. 3. Heated to 1000° (simply polished).



FIG. 4—Casting No. 5. Heated to 1000° (simply polished).

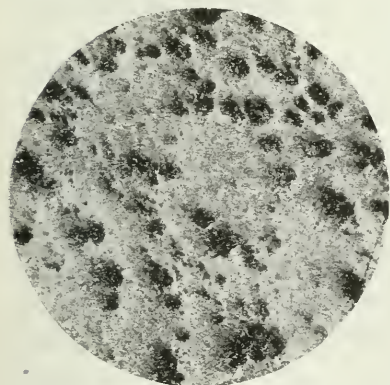


FIG. 5—Casting No. 5. Heated to 800° (simply polished.)

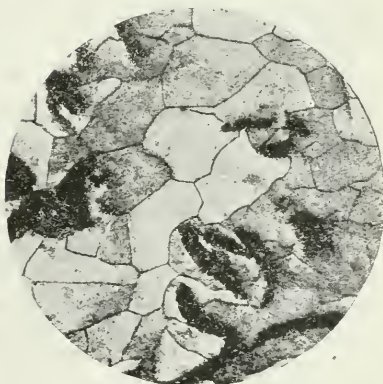


FIG. 6—Ferrite and graphite.

in order to be able to eliminate the influence of variations of carbon, either due to a partial decarburation during the annealing or to some irregularities of composition in the ingot, which we have thought necessary to correct.

(1) *The separation of graphite is induced at a lower temperature according as the percentage of silicon is greater.*

Thus, for the casting No. 1, which contains only some traces of silicon, a prolonged heat at a temperature of $1,100^{\circ}$, or at a lower temperature, does not cause any separation of graphite. But, at $1,150^{\circ}$, the separation of graphite takes place.

In the casting No. 2, after heating four hours at 700° , 800° , 900° and $1,000^{\circ}$, we observe no trace of graphite, but the graphite appears after heating to $1,100^{\circ}$.

In the casting No. 3, the graphite appears as traces after heating to 800° .

In the castings Nos. 4 and 5, a temperature of 650° is sufficient to separate carbon. In the last, in particular, after heating for six hours at 650° the proportion of graphite increased from 0.10 to 2.83 per cent.

(2) *The separation of graphite, once having commenced, continues at temperatures lower than that which induced the reaction.*

Thus, a small piece of casting No. 1 heated to $1,170^{\circ}$ and quenched, contained only 0.50 graphite and 2.61 of combined carbon. Another fragment of the same casting, heated for the same time to $1,170^{\circ}$ and cooled slowly to 700° , then quenched, contained 1.87 per cent. of graphite and 0.43 of combined carbon.

Likewise, a fragment of No. 3, heated to $1,170^{\circ}$ and quenched, contained 1.42 per cent. of graphite and 1.69 of combined carbon. Another fragment heated to $1,170^{\circ}$ and cooled slowly to 700° , then quenched, contained 2.56 per cent. of graphite and 0.38 per cent. of combined carbon.

(3) *At a constant temperature the separation of graphite is effected progressively at a slower rate of speed according as the temperature is lower and the percentage of silicon is less.*

Thus, for the casting No. 3, with 0.80 silicon, we obtain:

TABLE II.

Period of Heating.	Temperature.	Graphite.	Combined Carbon.
	deg.		
One hour	800	0'10	3'19
Four hours	800	0'22	3'07
One hour	900	0'30	2'97
Two hours	900	0'60	2'40
Four hours	900	1'58	1'14
One hour	1000	0'37	2'94
Two hours	1000	1'50	1'41
Four hours	1000	1'47	1'29

The following are some figures relative to casting No. 4 with 1'20 per cent. silicon :

TABLE III.

Period of Heating.	Temperature.	Graphite.	Combined Carbon.
	deg.		
One hour	700	0'6	3'42
Two hours	700	0'11	3'30
Four hours	700	0'20	3'13
One hour	800	0'12	3'68
Two hours	800	0'51	2'47
Four hours	800	1'64	1'56
One hour	900	2'28	0'90
Two hours	900	2'32	0'90
Four hours	900	2'35	0'99

Finally, the following figures relate to casting No. 5 with 2 per cent. silicon :

TABLE IV.

Period of Heating.	Temperature.	Graphite.	Combined Carbon.
	deg.		
One hour	700	1'39	1'90
Two hours	700	2'09	1'19
Four hours	700	2'67	0'28
One hour	800	2'36	0'78
Two hours	800	2'31	0'89
Four hours	800	2'43	0'54
One hour	900	2'33	0'58
Two hours	900	2'32	0'90
Four hours	900	2'33	0'90

We observe that for the last casting, the equilibrium is attained at the end of one hour at 900° , since the percentage of graphite does not vary on prolonging the time of heating to four hours. In the casting No. 3, with 0.80 silicon, the equilibrium is far from being attained at the end of four hours at the same temperature. For castings lower in silicon the phenomenon is not so clearly observable, because the transformation is not induced at temperatures lower than $1,100^{\circ}$, in spite of prolonged heating.

(4) *The percentage of combined carbon which corresponds to the equilibrium at a given temperature diminishes as the percentage of silicon increases.*

The following table gives the figures observed after four hours heating at different temperatures. For castings Nos. 1 and 2 we have induced the reaction by first heating to $1,150^{\circ}$ and $1,100^{\circ}$, and cooling slowly to a given temperature.

TABLE V.

Samples.	To 1100° Deg.		To 1000° Deg.		To 900° Deg.		To 700° Deg.	
	Graphite.	Combined Carbon.	Graphite.	Combined Carbon.	Graphite.	Combined Carbon.	Graphite.	Combined Carbon.
No. 1 . . .	1.15	1.74	1.03	1.74	—	—	1.87	0.43
" 2 . . .	1.26	1.93	1.00	1.62	—	—	—	—
" 3 . . .	1.61	1.26	1.60	1.52	1.67	1.17	2.56	0.38
" 4 . . .	2.10	1.02	2.20	0.95	2.32	0.90	—	—
" 5 . . .	2.18	1.00	2.10	0.93	2.33	0.90	2.67	0.25

(5) *The percentage of combined carbon which corresponds to the equilibrium is diminished as the temperature is decreased.*

The figures already cited indicate this diminution; we will give, moreover, the results obtained in two series of experiments in which we have sought to approach as closely as possible the state of equilibrium.

For that purpose, specimens of castings 1 and 3, surrounded by pulverized wood-charcoal have been heated to $1,170^{\circ}$, then cooled very slowly at about 50° per hour to

different temperatures; we maintained these temperatures for two hours and then quenched. For temperatures below 900° the operations lasting more than one day have been made many times; that is to say, they have been arrested at 900° and allowed to cool, then on the following day reheated to 900° and again cooled slowly. We obtained the following results:

TABLE VI.

Temperatures.	Sample No. 1.		Sample No. 3.	
	Graphite.	Combined Carbon	Graphite.	Combined Carbon.
deg.				
1170	0.50	2.61	1.42	1.69
1100	1.15	1.74	1.49	1.48
1000	1.03	1.74	1.35	1.55
900	—	—	1.91	0.99
800	1.15	1.31	2.09	0.43
700	1.87	0.43	2.56	0.38

The microscopic examination of many treated specimens confirms the results of chemical analysis, without adding much information. In the original state the castings present all the known aspects of white-iron castings.

The *Fig. 1* reproduces one of these specimens; the white parts corresponding to cementite, the dark parts to martensite. When we anneal at different temperatures the castings deprived of silicon, we modify the respective dimensions of these elements and cause variation in the concentration of the martensite following the laws already known.

In the castings containing silicon, we see, moreover, the graphite becomes readily visible by simple polishing, without etching with chemicals. The aspect of the separated graphite varies with the temperature of separation, and with the content of silicon. We give here some micro-photographs.

When we examine certain specimens in which we have sought to obtain the equilibrium at low temperatures, we recognize that the transformation is more advanced in cer-

tain regions where the graphite is found directly in contact with the ferrite.*

In *Fig. 6* is given an example obtained from casting No. 1, which contains only a trace of silicon. It is probable that these regions are those in which the transformation is complete, consequently, the stable condition, when cold, of the iron-carbon systems corresponds to the co-existence of two phases—pure iron and graphite; all the other forms in iron and steel, and notably cementite being unstable at a low temperature. The case of iron-carbon systems resembles somewhat that of phosphorus, for which the stable form, when cold, is red phosphorus, but that which we

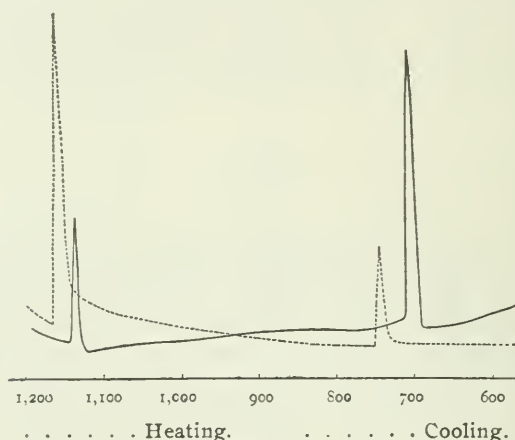


FIG. 7.

obtain and utilize most frequently is the unstable form of white phosphorus.

We have also determined the *critical points* of castings studied by the pyrometric method. For the different castings we have always observed two critical points very clearly, practically at the same temperatures. The first which is produced at about 700° corresponds to the resolution of pearlite. It is too well known to require space for argu-

* M. Osmond has already shown a case in which he observed the ferrite in contact with graphite. *Bulletin de la Société d'Encouragement*, Nov. 30 1900, page 657.

ment. The second is observed at about $1,150^{\circ}$; it is extremely sharply defined, as indicated in *Fig. 7*, which reproduces the heating and cooling curves observed with a casting low in silicon. It is produced under the same conditions with the castings high or low in silicon.

The following table indicates the temperatures at which it has been observed for the various castings:

TABLE VII.

Sample.	Heating.	Cooling.
No. 1	1140	1120
No. 2	1165	1145
No. 3	1137	1130
No. 4	1165	1137
No. 5	1165	1145

It has not been possible for us to determine whether this critical point corresponds to the resolution of mixed martensite-graphite eutectic, or to that of mixed martensite-cementite eutectic. Possibly there is a mingling together of these two transformations, which would be a much nearer approach than is indicated in the Roozeboom diagram.

One peculiarity interesting to note, is that the critical point of $1,150^{\circ}$ in all these castings is much more accentuated in the heating than in the cooling. It is the reverse of that which we observe ordinarily for the critical points.

The observations contained in this note indicate already that a certain number of points in the diagram of Roozeboom should be modified, but it seems necessary to have still other experiments before proposing a new diagram.

FORMATION OF NATURAL PARAFFINS.

Numerous theories have been put forward at different times to account for the formation of natural paraffins, the one received with most favor being that due to Berthelot and developed by Mendeléeff, in which the action of steam upon metallic carbides was regarded as the main source of the hydrocarbons. The chief stumbling block to this view was the difficulty of explaining the mode of formation of the naphthenes of the Russian oilfields. The researches of MM. Paul Sabatier and J. B. Senderens on the action of reduced nickel, iron and other metals upon hydrocarbons have now placed the "chemical" theory of petroleum formation on a firm experimental basis. By the direct hydrogenation of acetylene in the presence of nickel they have obtained liquid mixtures of hydrocarbons which can be made to correspond either with American or Caucasian petroleum by varying the conditions of the experiment. To account for the formation of petroleum it is thus sufficient to admit that there are in the depths of the earth free alkali metals and metallic carbides, which in contact with water give rise to mixtures of hydrogen and hydrocarbons. These gases encounter nickel, cobalt or iron in a finely divided state, and thus give rise to the mixtures of hydrocarbons forming natural petroleum.—*London Nature*.

THE RAILROADS OF THE WORLD.

The *Archiv für Eisenbahnwesen*, which has now for many years published statistics of mileage of the railroads of all countries in the world with some other data, says the *Railroad Gazette*, gives a somewhat more extended review in its last number, in which the figures are brought up to 1900, and so make a record of the work of the last century. The mileage built in each decade has been for the world :

1830-40	4,772	1870-80	101,081
1840-50	19,198	1880-90	152,179
1850-60	43,160	1890-1900	107,421
1860-70	63,255		

The mileage built before 1830, insignificant in amount, is included with the 4,772 miles credited above to the decade, 1830-40.

Of the total of 491,066 miles completed at the end of the century, more than one-half had been built since 1880 and nearly three-fourths since 1870. The total built in the forty years down to 1870 (130,385 miles) was one-seventh less than the construction in the single decade ending with 1890. It is noticeable, however, that in the last decade of the century 44,758 miles less were built than in the preceding ten years. This is one of the indications that the civilized and productive industrial countries of the world are now generally well equipped with these instruments of transportation. Europe (except Russia) and North America have immediate need of no large additions to their mileage. There is still abundant room for railroads in Asia, Africa and South America, but the slow growth of industries on these continents, two of which are over rather than under populated, but whose population is to a great extent a bar to progress such as Europe and North America have had in the past century, gives no promise of rapid railroad extension.

Note on Some Experiments with a New Form of Pressure Regulator.*

BY WILLIAM KENDRICK HATT, C.E., PH.D.

Professor of Applied Mechanics, Purdue University.

General.—The writer here records some experiments which were made under his direction in the Engineering Laboratory of Purdue University on a new apparatus by Mr. Will Hull, of the Class of 1901, who developed the details of the apparatus at the suggestion of Mr. J. T. Wilkin, Engineer for the Connersville Blower Company, Connersville, Ind.

The apparatus (*Fig. 1*) consists essentially of an expanding nozzle and a flat circular disc, against which the jet from the nozzle is directed, the disc being enclosed in a suitable chamber. The action is similar to that of the well-known ball nozzle, and the disc replaces the ball. In case of the ball nozzle the back pressure forcing the ball against the jet is the pressure of the atmosphere. In the apparatus the disc is enclosed in a chamber, and the back pressure is the pressure of the water in the chamber. This pressure is greater than that in the rapidly moving sheet of water on the upstream face of the disc, so that the disc moves toward the nozzle until equilibrium is established. The disc thus automatically throttles the upstream.

When this apparatus is inserted in a pipe line the pressure on the down-stream face of the disc is preserved fairly constant (within the limits of the experiments and for certain range of pressure in case of the apparatus used) while the upstream pressure varies within wide limits. The principle of the apparatus will have an application whenever it is desired to deliver water at a constant pressure to a machine from a source of supply subject to fluctuations of pressure. Whether a design of disc and nozzle could be

* Read before Indiana Academy of Sciences, January 27, 1902.

reached which would regulate pressure in case of air or steam is not determined.

The experiments were initiated with the desire to obtain information which would serve as a basis for proportioning this apparatus to serve various conditions of pressure and delivery. The experiments were interrupted before that point was reached. The results obtained with the apparatus are generally interesting, and it seems worth while to record them.

Mr. Hull used various combinations of disc and nozzle until he found the proper combination which would regulate the pressure used in case of the apparatus available.

In brief, he found that a nozzle of form specified in *Fig. 2* (called a $\frac{1}{4}$ -inch nozzle) in combination with a 2-inch flat disc would regulate the pressure in a $\frac{1}{2}$ -inch pipe to the following extent :

The pressure on the down-stream section of the pipe was preserved constant at $2\frac{1}{2}$ pounds per square inch by the action of the disc while the pressure of the upstream section varied between 10 to 40 pounds per square inch by gage (as shown on *Fig. 4*.)

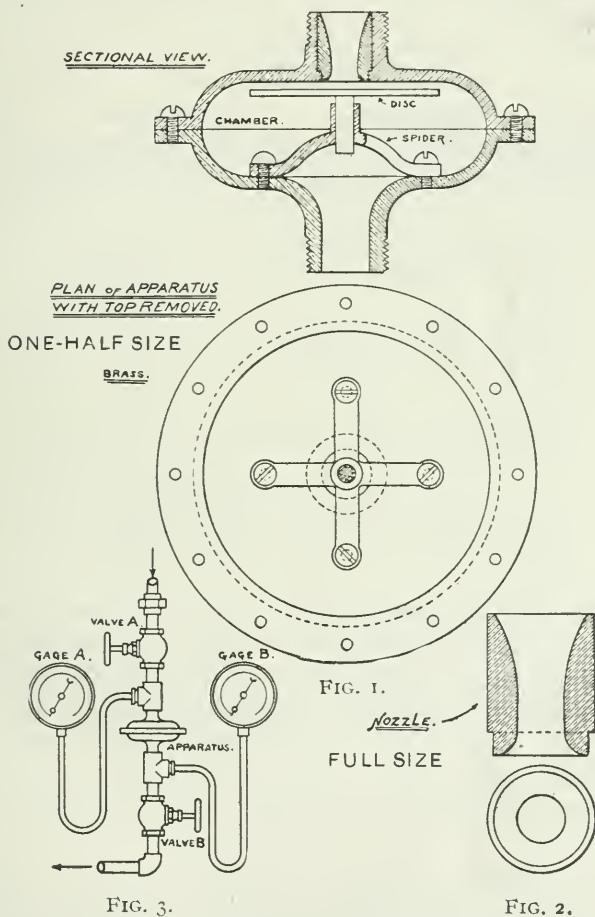
APPARATUS.

Fig. 1 shows the construction of the apparatus with nozzle, disc, chamber and spider for supporting the disc. The fitting of the apparatus for experimental work is shown in *Fig. 3*. The two gages for measuring the pressures were placed as close as possible to the chamber containing the disc. The fittings were made with great care. The valves shown were for controlling the pressures used in experimentation.

METHOD OF EXPERIMENT.

The apparatus was attached to the standpipe of the hydraulic laboratory, the pressure in which was controlled by a steam pump. Starting with a given standpipe pressure, say 40 pounds by gage, the water was allowed to flow through the apparatus, being throttled by the lower valve to indicate a down-stream pressure of, say, $2\frac{1}{2}$ pounds per square inch on the lower gage. This down-stream pressure

was allowed to remain fixed during the test, the lower valve not being disturbed. The upstream pressure was varied by use of the upper valve, throttling the upstream section. In this way upstream pressures of from 40 pounds per square inch down, by steps of 5 pounds per square inch, to the lower



limit were effected. The apparatus discharged into a weighing tank and the discharge was weighed. The temperature of the water was taken every minute, because this temperature varied greatly throughout the tests, due to the fact that the standpipe tank was connected to the condenser of a

Corliss engine. With respect to the effect of temperature on the results, it may be said that when the temperature of the discharge rose above the 100° F. the tail pressure-gage showed a very unsteady pressure, the needle vibrating with a range of as much as one-half pound. The disc was no doubt at this time subject to vibrations, which, when the temperature of the water rose to 110° F., were of such frequency as to cause a musical note. Under the latter condition the needle was too sluggish to respond and remained at a fixed position. The movement is probably connected with alternate periods of vaporization and condensation of the water on the upper side of the disc.

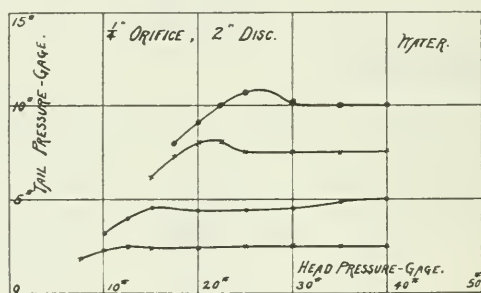


FIG. 4.

Results.—The following combinations of nozzle and disc were used: $\frac{1}{8}$ -inch nozzle, 1-inch disc; $\frac{1}{8}$ -inch nozzle, $1\frac{1}{2}$ -inch disc; $\frac{1}{8}$ -inch nozzle, 2-inch disc; $\frac{3}{16}$ -inch nozzle, 1-inch disc; $\frac{3}{16}$ -inch nozzle, $1\frac{1}{2}$ -inch disc; $\frac{3}{16}$ -inch nozzle, 2-inch disc; $\frac{1}{4}$ -inch nozzle, 1-inch disc; $\frac{1}{4}$ -inch nozzle, $1\frac{1}{2}$ -inch disc; $\frac{1}{4}$ -inch nozzle, 2-inch disc.

Of these, the $\frac{1}{4}$ -inch nozzle gave successful results; the $\frac{1}{4}$ -inch nozzle with the 2-inch disc gave the best results. These are shown in *Fig. 4*. In working the head pressure down toward the tail pressure the former would approach a critical point at which the difference of pressure became so slight that the regulating effect ceased and both head and tail gages suddenly moved to the same reading. The disc at this period no doubt dropped away from the jet. That is, a certain difference of pressures is needed to enable the appa

ratus to work. This difference of pressure became greater as the tail pressure was increased, as is shown in *Fig. 4*.

In experiments with the other orifices mentioned, the lines shown in *Fig. 4* became straight lines inclined to the horizontal. The hump in *Fig. 4* was characterized by an unsteady head pressure.

WATER.

$\frac{1}{4}$ " ORIFICE

2" DISC.

GAGE PRESSURE.		DISCHARGE PER MIN. CU. FT.	TEMPERATURE OF WATER.	GAGE PRESSURE		DISCHARGE PER MIN. CU. FT.	TEMPERATURE OF WATER.
HEAD.	TAIL.			HEAD.	TAIL.		
40 #	2.5 #	0.301	105 F	40 #	7.5 #	0.334	88 F
35	2.5	0.304	105	35	7.4	0.337	92
30	2.5	0.304	108	30	7.5	0.342	93
25	2.5	0.304	109	25	7.5	0.342	93
20	2.4	0.300	112	22.5	8.2	0.342	95
15	2.4	0.300	112	20	8.	0.350	96
12.5	2.5	0.304	111	17.5	7.25	0.323	95
10	2.3	0.282	106	15	6.2	0.314	94
7.5	1.9	0.267	112				
-----	-----	-----	-----	-----	-----	-----	-----
40	5	0.330	95	40	10	0.377	82
35	4.8	0.322	100	35	10	0.385	81
30	4.5	0.315	99	30	10.2	0.388	80
25	4.4	0.306	97	25	10.7	0.388	78
20	4.4	0.306	100	22.5	10	0.385	78
17.5	4.5	0.315	105	20	9	0.361	78
15	4.5	0.315	104	17.5	8	0.336	78
12.5	4.	0.302	105				
10	3.2	0.270	108				

FIG. 5.

One disc was beveled so as to give a constant area of passage-way to the expanding ring of water; that is, it was dished, with the deepest part next to the nozzle. This disc preserved a constant difference of pressure between the head and tail pressures.

Some experiments were carried on with air as the fluid passing through the pipes. With the nozzle and discs used

there appeared to be no governing effects in case of these air pressures.

In general, it may be said that the shape of the nozzle has most to do with the action observed. A number of nozzles of different form were used; those most nearly like that shown on *Fig. 2* gave the best governing effect.

The size of the disc affects the results obtained with any given nozzle. The 2-inch disc gave better results than the 1-inch or the 1½-inch disc.

The action desired could be obtained with water at a temperature of 75° F. as well as at the higher temperatures.

A very pretty cylindrical sheet of water could be obtained by removing the lower part of the casing. The disc acted like the well-known ball nozzle. Under these conditions, with a head pressure of 40 pounds and a nozzle velocity (as figured from the discharge) of 14.6 feet per second, it was found necessary to exert a force of 9 pounds to pull the disc from the jet.

IMPROVEMENT IN THE METALLURGY OF ALUMINUM.

The hydrate of aluminum, like most colloidal precipitates, retains with great tenacity considerable quantities of the precipitant and also of the radical with which it was before combined, a most unfortunate circumstance from a metallurgical point of view, for as the hydrate is separated by the reaction of carbonic acid gas on sodium aluminate, very appreciable percentages of sodium carbonate, amounting in some cases to 7 per cent., are held by the precipitate, and passing into the electrolytic cell are decomposed, resulting in the contamination of the aluminum with more than mere traces of the alkali metal. Mr. H. W. Jordan, of Syracuse, observes that the amount of salt so retained is governed largely by the temperature of the reacting gas and that by superheating the carbonic acid to a temperature above the normal boiling point of the aluminate solution, and preferably to 400° F., the quantity of carbonate held by the hydrate can be reduced below one-half of one per cent.—*Electrical World*.

MOVING A BRIDGE.

An engineering feat, which for magnitude and quick execution has seldom been equaled, was accomplished on May 25 at New Brunswick, N. J., by the Pennsylvania Railroad Company. The bridge crossing the Raritan river and the draw connecting, which span the Delaware and Raritan Canal, were moved 14 feet 6 inches in one minute and forty-three seconds. The length of the bridge and draw is 906 feet. The bridge has five spans, each 150 feet long, and the draw span is the same length. There was no interference with the regular railroad schedule.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, February 19, 1902.

President JOHN BIRKINBINE in the chair.

The Metric System of Weights and Measures.

(Continued from page 72.)

To the Franklin Institute :

In 1876 the Boston Society of Civil Engineers, in conjunction with many of the most active scientific societies in the country, issued a circular to all scientific and technical institutions of the United States, asking them to join in a petition to Congress to fix a date after which the metric weights and measures should be the only legal standards. The acceptance of this invitation was very general; but to the surprise and regret of many of its staunchest friends and the educated public generally, the Franklin Institute, through a majority of one of the committee of three it appointed to consider the subject, reported against the adoption of the metric system. The report of the minority of this committee, the late Mr. Robert Briggs, which was strongly in favor of the change, was published with the majority report in the *Journal of the Franklin Institute*, June, 1876 (Vol. ci, No. 606, p. 370 +). Mr. Briggs afterwards participated in the joint discussion held by the American Institute of Mining Engineers and the American Society of Civil Engineers in New York, February, 1877. The objections of the two gentlemen, Dr. Coleman Sellers and Mr. W. P. Tatham, constituting the majority of the Franklin Institute's committee, were roughly as follows:

(1) Some reform of weights and measures in France was necessary when the metric system was adopted, but none was necessary in the United States, where the weights and measures are uniform by law (?).

(2) The terrible French Revolution was invoked to disparage any proposition emanating from French soil.

(3) The character and habits of the French people were similarly used.

(4) Most of the points of John Quincy Adams' report were reproduced and his question of the power of the Government to "fix" a standard.

(5) The meter was said to be a less convenient measure than the 2-foot rule.

(6) By changing our unit it was urged we would destroy our conformity with Great Britain.

(7) The change would entail too great expense.

TABLE I.—COMPARATIVE CHART OF METRIC LINEAL MEASURE.

	Millimeter.	Centimeter.	Decimeter.	Meter.	Dekameter.	Hektometer.	Kilometer.	Myriameter.
Millimeter	1	10	100	1000	10000	100000	1000000	10000000
Centimeter	0'1	1	10	100	1000	10000	100000	1000000
Decimeter	0'01	0'1	1	10	100	1000	10000	100000
Meter	0'001	0'01	0'1	1	10	100	1000	10000
Dekameter	0'0001	0'001	0'01	0'1	1	10	100	1000
Hektometer	0'00001	0'0001	0'001	0'01	0'1	1	10	100
Kilometer	0'000001	0'00001	0'00001	0'001	0'01	0'1	1	10
Myriameter	0'0000001	0'0000001	0'0000001	0'00001	0'001	0'01	0'1	1

TABLE II.—COMPARATIVE CHART OF ENGLISH LONG MEASURE.

	Barley-corns.	Inches.	Hands.	Links.	Feet.	Yards.	Fathoms.	Rods.	Chains.	Furlongs.	Miles (st.)	Miles (ge.).	Leagues.
Barleycorns	1	3	12	23 76	36	108	216	594	2376	23760	190080	220176	570240
Inches	1'33	1	4	7'92	12	36	72	198	792	7920	63360	73392	190080
Hands	0'083	0'25	1	1'98	3	9	18	49 5	198	1980	15840	18348	47520
Links	0'042	0'126	0'555	1	1'515	4'545	9'09	25	104	1000	8000	9266 66	24000
Feet	0'0278	0'83	0'33	0'66	1	3	6	16 5	66	660	5280	6116	15840
Yards	0'0092	0'278	0'111	0'22	0'33	1	2	5'5	22	220	1760	2038'66	5280
Fathoms	0'0046	0'139	0'0555	0'11	0'165	0'5	1	2'75	11	110	880	1019'33	2640
Rods	0'00167	0'0505	0'202	0'04	0'0606	0'1818	0'3636	1	4	40	320	370'66	960
Chains	0'000421	0'01262	0'00595	0'01	0'01515	0'04545	0'0909	0'25	1	10	80	92'66	240
Furlongs	0'0000421	0'001262	0'000595	0'001	0'001515	0'004545	0'00909	0'025	0'1	1	8	9'266	24
Miles (st.)	0'000000421	0'00001262	0'00000595	0'000012	0'0000189	0'0000545	0'000109	0'0003125	0'00125	0'125	1	1'1582	3
Miles (geo.)	0'000000454	0'0000136	0'00000545	0'0000108	0'0000163	0'0000494	0'0000981	0'000297	0'0010792	0'10792	0'864	1	2'59
Leagues	0'000000175	0'000000546	0'000002103	0'00001	0'000066	0'0001836	0'0003786	0'0010416	0'004166	0'04166	0'3333	0'380666	1

TABLE III.—SHOWING THE RELATION OF ENGLISH TO METRIC LINEAL UNITS

Meters.		Meters.		
		0'001	Millimeters.	1
		0'002		2
		0'003		3
		0'004		4
		0'005		5
		0'006		6
		0'007		7
		0'008		8
0'00846	Barleycorn	0'009		9
		0'01	Centimeters	1
		0'02		2
0'0254	Inch (=3 barleycorns)	0'03		3
0'0305	Foot tenth (=1'2 inches)	0'04		4
		0'05		5
0'05715	Nail (=2'25 inches)	0'06		6
		0'07		7
		0'08		8
		0'09		9
0'1016	Hand (=4 inches)	0'1	Decimeters.	1
0'1558	(Cube root of wine gal. or 231 cub. in.=6'1538 in.) }	0'2		2
0'1665	(Cube root of beer gal. or 282 cub. in.=6'5576 in.) }	0'3		3
0'2012	Link (=7'92 inches) }	0'4		4
0'2286	Quarter (=9 inches) }	0'5		5
0'3048	Foot (=12 inches) }	0'6		6
0'3278	Cube root of bushel (=1'907 inches) }	0'7		7
		0'8		8
0'5715	Ell Hamburg (=2¼ quarters)	0'9		9
0'9144	Yard (=3 feet) }	1	Meters.	1
0'9837	Cubic root of wine tun = 38'78 inches }	2		2
1'143	Ell English (=5 quarters) }	3		3
1'3716	Ell French (=6 quarters) }	4		4
1'5631	Cube root of cord (=5'0397 feet) }	5		5
1'829	Fathom (=6 feet) }	6		6
		7		7
		8		8
		9		9
5'0292	Rod, pole or perch (=5'5 yards)	10	Dekameters.	1
		20		2
20'1164	Chain (=4 rods=22 yards)	30		3
		40		4
		50		5
		60		6
63'6148	Square root of an acre (=69'57 yards)	70		7
		80		8
		90		9
		100	Hektometers	1
		200		2
201'168	Furlong (=10 chains=40 rods)	300		3
		400		4
		500		5
		600		6
		700		7
		800		8
		900		9
1609'34	Statute mile (=8 furlongs) }	1000	Kilometers	1
1863'62	Geographical mile (=1'158 statute miles) }	2000		2
		3000		3
		4000		4
4823'02	League (=3 statute miles)	5000		5
		6000		6
		7000		7
		8000		8
		9000		9
		10000	Myriameters.	1

(8) The measurement of every plot of ground in the United States had been made in acres, feet and inches.

(9) But *all* of the objections against the metric system did not apply to the decimal division of the present units (!).

The present writer answered these points specifically in a paper read before the Philadelphia Social Science Association on December 28, 1877, and Mr. John W. Nystrom, then a leading and active member of the Institute, recognizing the impossibility of introducing his tonal (or sixteen) system, and at the same time appreciating the immense advantage, over any other yet devised, of the metric system, strongly supported it and condemned the majority report of the Franklin Institute's committee.

At this time the American Metric Bureau, through its Secretary, Mr. Melvil Due (Melville Dewey), was active in having the metric system introduced as a compulsory study into the primary schools, in endeavoring to arouse public opinion to the necessity of securing uniformity with the rest of the world, and in urging its adoption by the United States.

As long ago as 1860 the values of exports and imports of countries using the metric system were respectively seventeen and fifteen times those of countries not using it. Since then Germany and many smaller countries have adopted it and the disparity between the two classes is much greater. The only three large countries which have not completely substituted it, viz. : Russia, England and the United States, have all legalized it in part, and the legislative bodies of the last two have several times been within a few votes of adopting it exclusively.

Some of its advantages are : (1) in the immense saving of time and avoidance of the danger of errors in computations by at once exhibiting the relations of linear and cubic space, weight and specific gravity, and preserving them throughout the usual mathematical operations.

(2) The production of an infinite scale in which the units of measure are equally distributed ; from the infinitesimal, used in calculating the diameters of molecules, to those employed in stating the distances apart of celestial bodies. The Anglican system consists of groups of incommensurable units unevenly scattered over a few areas of the entire gamut of measure.

(3) Even if the unit base, the concrete meter stick, should prove to be more or less than the exact ten-millionth of a quadrant of the earth's meridian anywhere, its actual value is fixed, as all other lineal measures have been, by carefully prepared standards, and by the carefully observed phenomena of their relations to the second's pendulum at many points of the earth's surface. When uniformity among civilized nations is once established, should it ever be thought desirable to secure closer approximation to any natural terrestrial unit, this can easily be done by mutual agreement and by all nations together.

A detailed consideration of the whole subject will be found in my paper before cited, and in a paper by me read April 5, 1878, before the American Philosophical Society, on the interconversion of the metric and English units.

I have added the three tables from the first of the papers above referred to, for the purpose of illustrating the greater simplicity and the more perfect adaptability to the measurement of very large or very small quantities, of the metric system.

A comparison of Tables I and II will show the enormous difference between the two scales in the facility which they respectively offer for the conversion of one unit into another.

Table III shows but a single English measure between 8 and 9 of the first group of ten in the metric scale. Three English units appear between the 2 and 7 of the second (centimeter-decimeter) group of ten. Seven units are seen between the 1 and 5 of the decimeter-meter group, and two beyond the 9 of this group. Four units lie between the 1 and 2, and one between the 5 and 6 of the meter-dekameter group of ten. Two units occur within the dekameter-hektometer ten; one within the hektometer-kilometer ten; and three between the kilometer-myriameter ten.

There are no other named English measures, but the metric units have just begun. By the same simple decimal division and multiplication, as many more groups of ten of the infinitesimal or of the greatest units may be at once provided, each so related to the ordinary units by similar and uniform multiples that the determination of the value of one unit in terms of any other involves no transaction more difficult than the transfer of a decimal point.

If we desire to convert yards into geographical miles, or barleycorns into links, much more time would be necessary and much greater liability to error incurred.

But the great merit of the system is seen when one wishes to calculate rapidly the weight of, say, commercial oil of vitriol in a given cubic content.

The weight in metric tons (a unit closely approximating the English short ton) is the product of the length, breadth and height in meters and the specific gravity (1.84 in the case supposed) of the fluid, water at specified temperature and barometer being 1.

In conclusion, I would refer to the very able and exhaustive report on the adoption of the metric system and on metric coinage presented by the Committee on Coinage, Weights and Measures of the House of Representatives of the 46th Congress, 1st Session, Report No. 14, Alexander H. Stephens, chairman.

Respectfully,

ROOM 1042 DREXEL BUILDING,

PERSIFOR FRAZER.

PHILADELPHIA, February 7, 1902.

THE TABOR MANUFACTURING COMPANY.

PHILADELPHIA, February 18, 1902.

To the Secretary :

In response to your request for an expression of my views on the adoption of the metric system in the United States, and in view of the possibility of being unable to attend the meeting of the Franklin Institute to consider the question to-morrow night, I may say that I was led to endorse the action of the special committee of which I am a member, from the preponderance of evidence in its favor, and not because I consider the metric system as ideal in every respect.

I have never regarded it with favor from the standpoint of practical utility in the workshop, because the numeration does not permit of continuous subdivision by 2.

This inherent defect, for which the system is not primarily responsible, can, of course, never be eradicated except by a revolution which would for a time involve the whole industrial world in a chaos of doubt and confusion. The benefits to be derived from a change in our system of arithmetical notation are obvious, but the difficulty of unlearning the multiplication tables to which we are accustomed, and learning new ones which will more perfectly harmonize the practical and theoretical conditions to be met, seems to me insurmountable.

There are too many or not enough unit figures in the Arabic system of notation, and the simplest conceivable change would be to obliterate the numerals 8 and 9. If this were done we would then have a decimal system capable of continuous subdivision by 2, and a metric system adapted to this notation would be ideal in every respect. Subdivision by 2 is the simplest and most natural method of scaling down, and that it will continue to assert itself whether the metric system prevails or not is evidenced in many ways. We have already a decimal currency, but in spite of this, stocks continue to be quoted in fractions of halves, quarters, eighths and sixteenths, and brokers take commissions of $\frac{1}{8}$ and $\frac{1}{16}$ of 1 per cent. The kilogram is divided into halves and quarters, for the convenience of tradesmen, and the tendency to divide all metric units in the same way, thus leading to longer and longer decimals in the expression of values, can never be checked. And again, for lineal dimensions there is no scale comparable in clearness with that formed by the natural method of continuous subdivision by 2, and in the use of such a scale for drawing, no decimal scale can compare with it in adaptability.

That the metric system does not lend itself to this natural method of subdivision seems to me deplorable but irremediable in our present advanced stage of civilization.

We have started wrong and cannot change however much we may desire to do so; the accumulations of knowledge are too vast to be modi-

fied, and as a matter of fact there is no alternative but to accept the inconvenient Arabic system of notation as forever fastened upon us.

Then, having done this, it is perfectly clear that there is but one system of weights and measures in the world to-day, and the best that can be devised on the notation to which the whole world is committed.

The practical convenience of the workshop must, I believe, give way to the overwhelming theoretical advantages of the metric system. These advantages cannot be successfully disputed, and I have therefore been compelled reluctantly to admit the adoption of the metric system as a wise step for this country to take. Any system is better than none at all, and no system founded on the natural subdivision by 2 would with our present notation be acceptable to the great army of thinkers who plan the work of the world.

Therefore, let us have the best attainable, though it may not be the best conceivable.

Yours truly,

WILFRED LEWIS.

BROWN & SHARPE MANUFACTURING COMPANY.

PROVIDENCE, R. I., February 18, 1902.

To the Secretary :

We have yours of February 1st, giving notice of the meeting, the discussion before the Institute, and its committee's report on the "feasibility and advisability of adopting the metric system of weights and measures in the United States."

We regret that we shall not be able to attend this meeting or to send any representative.

We would understand that the purport of such report as has been made is the support of certain legislation by the National Government, which is favorable to a general adoption of the metric system of weights and measures in this country. We would say that in general we are opposed to such legislation for several reasons.

In the absence of convincing argument to the contrary, we would feel, first, that the metric system in itself is not a better system than the English for the purposes of engineering trade; and secondly, even granting its merit, we question whether any such enactments of the National Government would accomplish the desired ends. We believe the American people are too much wedded to the English system to give it up because of any national legislation. We well know that the support of the Franklin Institute will carry more or less weight for or against the proposed measure, and trust that, if it is deemed advisable to adopt any measures of such character, it will be along the most conservative lines. We are

Respectfully yours,

BROWN & SHARPE MFG. CO.,

HENRY D. SHARPE.

GENERAL ELECTRIC COMPANY.

LYNN, MASS., February 13, 1902.

To the Secretary

I am glad to note that a special committee of the Franklin Institute has taken up the question of the adoption of the metric system for our standards, and has reported upon the matter favorably.

In my opinion we need the system, and I hope it will become international. We need it because it is a rational system connecting measures of length with those of area, volume, etc. It appears to me that our people have been long enough under the incubus of "long" and "short" tons, "long" and "short" hundredweights, "dry" quarts, "liquid" quarts and the like; units without any rational relation, or often with curious fractional relationship to one another.

I doubt whether there are many persons who could state the various measures and their values as learned in childhood. If such measures as our measures of length in feet and inches were the only things concerned, I should not advocate a change, but the question is far broader than that of a set of linear units, and the metric system is the only existing rational system which can be substituted for the irrational measures we now have.

I realize that in changing to the metric system, many of our industries will be subjected to some confusion and perhaps considerable expense. I do not think the change can be forced or accomplished by any sudden, revolutionary, process. It seems to me that ample time should be allowed for the transition; in fact, a period of not less than two or three years.

While I have never regarded the measures of length of the metric system as the most ideal for practical purposes, still no better system exists, and it is decidedly too late to devise any new systems. I hope the National Government will soon enact such laws as will insure the ultimate adoption of the metric system as our standard.

I may add, in conclusion, that I have been in consultation with most of the heads of departments and engineers of the General Electric Company, and find that on the whole they are favorable to the adoption of the metric system, especially on new work, with the idea that it would eventually entirely displace existing measures. When it is borne in mind that in the business of machine manufacturing, the cost of gages and other tools made in standard dimensions is a large item, and that the change means the production of other gages, etc., in the new system, it is indeed surprising that so little opposition to the proposed change has arisen.

It is beginning to be generally believed, I think, that the ultimate advantage will be greater than the temporary disadvantage, and that the longer we go on without making the change, the more difficult and costly will the carrying out of any such substitution become.

Yours very truly, ELIHU THOMSON.

BEMENT, MILES & CO.

PHILADELPHIA, PA., March 3, 1902.

To the Secretary :

In the matter of adopting the metric system of weights and measures in the United States, our views upon the subject were not given upon first request, as we thought the matter required more consideration than we found time to give it, before placing ourselves upon record either for or against the change.

As the request has again been made for our opinion, can only say we give it from our point of view and in connection with our particular line of business. Were we to pass upon the simple question of the advisability of having a uniform standard throughout the civilized world, and without regard to the inconvenience and expense incidental to the change, we would decide in the affirmative. We would also be an advocate of adopting the metric system on account of it being more universally used than any one system, rather than to attempt to force the British standards, even though considered as convenient.

From what we have said thus far, you will see we are, in a general way, in favor of a common system of weights and measures, and the system should be the metric.

On the other hand, considering the matter in connection with our own manufacture, or, to make it more definite, our manufacturing establishment, we do not believe the time is opportune for adopting this system, as it would lead to considerable expense if it were carried out to a degree that would make it an international benefit. We could readily, and without much expense, express dimensions of tools, fixtures, etc., in metric symbols, but would this be any real advantage unless the pieces so expressed were exact duplicates of similar pieces in use by countries whose standard is the metric system?

Were the decimal system to be used, we would find it necessary, as a matter of economy and to be able to duplicate parts for repairs, to adhere to sizes now in use and merely express them differently. This sort of adopting the system would not, to our way of thinking, lead to the desired point.

To reach the object we are after, we would have to equip our places with new tools and fixtures that would be uniform in size as well as expression, among all nations using the metric system. This would mean, for many years, carrying a larger stock of tools, and of course increasing the investment without a corresponding increase in the output.

Considering the many exports made to countries where the metric system is in use, we have found it necessary in very few instances to conform to metric sizes, and in fact, only in such machines as lathes where the lead screw had to be a decimal pitch. These modifications

were readily made, and the balance of the machines made to our ordinary standard.

As we think the change would increase the expense and create more or less confusion, without materially increasing the sales, it is a natural conclusion that we would not favor the change until convinced the view taken by us is wrong.

Yours very truly,

BEMENT, MILES & Co.,

W. J. HAGMAN, *General Manager*.

TREASURY DEPARTMENT, OFFICE OF THE COAST AND GEODETIC SURVEY.

WASHINGTON, D. C., February 13, 1902.

To the Secretary :

Your courteous invitation to take personal part in the discussion of the report of your special committee on feasibility and advisability of the adoption of the metric system, is before me. I regret that circumstances prevent my being present, but I gladly avail myself of the invitation to submit some comments.

I doubt whether any discussion is needed of the broad subject whether a common system of weights and measures is desirable. That, I think, will be admitted by every one. Forty years ago, the question whether the British system or the metric would ultimately prevail may have been open to discussion. Now the progress of the latter, its adoption by Germany and by Norway and Sweden, its extension in Mexico and South America, its adoption by all scientific men in the researches from which results nearly all human progress, have settled that question.

Its progress among scientific men cannot be ascribed alone to the advantage of having a common system. It must be due largely to the fact that it is a labor-saving device of vast importance. Viewed from that standpoint alone, the temporary inconvenience and cost which a change might involve, would, in my judgment, be insignificant as compared with the inconvenience and cost which the continued use of the customary weights and measures entail on every generation of our rapidly growing population on account of the loss of time and waste of mental energy involved in the use of our heterogeneous weights and measures.

It is not a new thing to change weights and measures. Aside from the recent example set by other nations in the radical adoption of the metric system, the English weights and measures have continually undergone change, though the names may have been retained.

In our country the agrarian measure of the arpent has disappeared from the Louisiana Purchase. The vara was in use in the territories acquired from Mexico and California. The lack of inter-relation between our units of weight, length and volume clearly indicates that they

are the remnants of different systems, for no human ingenuity would ever have devised, at any one time, anything so wonderfully complex as our existing weights and measures.

It certainly is the province and duty of the Government to take part in the reform of its weights and measures. The Constitution has provided that Congress shall fix the standard of weight and measure, and, in the nature of things, individual effort can only be directed towards urging Congress to act, because the individual cannot adopt any particular system, though it may be permissive, for he is dependent on its adoption by others before it can be used profitably by himself except, of course, in intellectual pursuits.

The question may be raised, as it always has been, whether the time is opportune for the change. To this the answer seems to be that the difficulties are more apt to increase than to decrease with the lapse of time. The rivalry between commercial nations was never greater than now, and a common system of weights and measures is certainly a great aid in promoting an interchange of commodities.

There can be no doubt that Great Britain would promptly follow the lead of the United States. The fact is, these two nations seem to wait upon each other for the first step. The agitation for the adoption of the metric system is as great in England as it is in this country. It is true we are in fair accord with Great Britain, but we are out of tune with the southern half of our continent.

It cannot be believed that Mexico and South America will ever recede from the use of the metric system any more than that we will recede from our system of decimal coinage. Its extension and common use there seems certain, and it is also certain that those countries are sure to become of much greater importance in the commercial world than they are at present.

For all these reasons I am heartily in accord with the tenor of your resolutions.

Yours very truly,

O. H. TITTMANN,
Superintendent.

SMITHSONIAN INSTITUTION.

WASHINGTON, U.S.A., February 8, 1902.

The Committee of the Franklin Institute on the Adoption of the Metric System in the United States.

GENTLEMEN :—I am fully in accord with the report of the Franklin Institute that the metric system is commendable, not only as a suitable international standard, but for facility of computation and in other ways; and I approve of any modification which will promote the general introduction of the metric system with a minimum of loss.

I do not forget that the considerable capital invested in present standards and in machinery using them will be rendered nearly valueless by such a change, and, having this in view, I still think that the change would be worth more than any probable cost.

Very respectfully yours,

S. P. LANGLEY.

WILLIAM SELLERS & CO., INCORPORATED.

PHILADELPHIA, February 19, 1902.

To the Secretary.

SIR :—I am in receipt of your favor of the 1st inst., requesting me to express my views on the "feasibility and advisability of adopting the metric system of weights and measures in the United States." I have also received the report of the special committee of the Franklin Institute appointed to consider this subject, and the pamphlet of the American Metrological Society, advancing arguments in favor of the adoption of the metric system.

By "adoption" I understand is meant enforced adoption by legislative enactment, and presume that this question, which has been forced into prominence at intervals during the past century, is again re-opened because Congress is considering a bill designed with this intent.

I have not seen the text of this measure, but understand it requires all Departments of the general Government to use the French metric system except for land measurement, the expectation being, doubtless, that the resulting inconvenience to those dealing with the Government will tend to bring the French system into more general use.

I do not think any great hardship would be involved if the Government should require the Army and Navy stores—the coal, salt pork, hard tack, molasses, etc.—to be measured in kilograms and liters instead of pounds and gallons, although I confess I do not see any particular advantage in such a course; but before forcing this change on all Departments, I think the cost, direct and indirect, should be carefully considered.

The Government is a large buyer of many kinds of manufactured products, and, in order to buy at reasonable rates, must buy what the market supplies; that is, must use what other purchasers require. For example, we have certain standard sizes of pipes and fittings threaded with so many turns per inch; these are well recognized, and we are able to buy pipe of one man and valves or other fittings of another man with reasonable certainty that they will fit one another, and many expensive tools and gages are required to produce this degree of uniformity. Is it intended to forbid the Government to buy such pipe and fittings and require it to have made special pipes in millimeter sizes with

threads in millimeter pitches? It is hardly conceivable that any one understanding the subject should recommend such a course.

The case is the same with our convenient series of bar sizes, our sheet and wire gages, our bolts, nuts and screws and many other commercial standards in all branches of business. It is true that these conventional sizes are perhaps more or less crude and imperfect; but they are well understood and serve their purpose, and experience has shown how difficult it is to change them when better series have been suggested. It is said that we need not change any actual sizes, but simply call them by new names. For years we have been trying to increase the accuracy of the sizes of things—to have the inch bar or the inch bolt measure 1" in diameter and not more or less; but if we must call our 1-inch bar a 25 mm. bar, which it is not, it seems to me we are retrograding instead of progressing.

The great convenience that was expected from the decimal division of measures has proved largely a delusion, and it is admittedly impracticable to overcome entirely the natural tendency to binary division. It is admittedly impracticable to change our land measures and I believe equally impracticable to abandon our pipe and screw-threads, our wire gages and many other standards, as well as the vast amount of engineering data now stated in our present units. I cannot see that anything is possible but a partial introduction of the French system amounting certainly at first to a mere change of names.

If any one now desires to adopt or use all or any part of the French system he is at perfect liberty to do so. The Government has already legalized the French units and has moreover provided standards of weight and measurement to which all may refer. In my judgment the general Government has thus done its whole duty in the premises. I am not an advocate of that kind of despotic paternalism which interferes too much with the private affairs of the citizen. The French system has been gladly adopted in the laboratories of scientific men, and its further general adoption will proceed as rapidly and to the extent that the system proves itself better or more convenient in any way than the simplified English system which we now employ. It appears, however, that the advocates of the French system are not satisfied with the natural process of extension and therefore seek to bring about the general use of the system by legal coercion in the absence of any demand for such legislation from the people at large.

I believe that without a popular demand for such a change, any attempt to force the French system into use by legal coercion will prove largely abortive.

Yours truly,

C. SELLERS, JR.

PHILADELPHIA, February 10, 1902.

To the Secretary:

In reply to your circular letter of 1st inst. in regard to the metric system, I would say that I am most heartily in favor of the adoption of the report of the committee, with perhaps one slight exception. In weights and measures of capacity I have for many years worked with both systems, and by practical experience have found the metric system as far superior to our present system (or rather want of system) as our decimal currency is in advance of the English £ s. d.

When, a generation or two hence, the history of the present time is written, one of the things that will seem most incredible will be that a nation as far advanced in civilization as the United States is supposed to be, should be weighing its copper by one standard, its silver by another, its diamonds by a third and its medicines by a fourth, all of them interchangeable only by means of fractions, and measuring its wines by one system, its grain by another and its gas by a third.

The use of the metric system for weights and measures of capacity will cause the less inconvenience because of the fact that our present weights and measures are of comparatively large units, fine determinations in most cases being even now made in the metric system. Its use for lineal measurement will cause more difficulty, because of our present machines and tools having been made to inches and fractions, but I fully believe the temporary inconvenience will be much more than compensated by the convenience of the metric system.

However, it would seem to me to be not impracticable to inaugurate the system for weights and measures of capacity in advance of lineal measures, if it be thought by a majority that the change in lineal measurement is not advisable. Should it be adopted so far, its advantages will be so manifest that the other must follow in due course.

Truly yours,

THEO. D. RAND.

OFFICE OF THE CHIEF OF ENGINEERS, UNITED STATES ARMY.

WASHINGTON, February 10, 1902.

To the Secretary:

* * * I do not hesitate to say that I am heartily in favor of any movement which will bring about the adoption in this country of the metric system, with the least confusion and expense.

Very respectfully,

G. S. GILLESPIE,

Brig. Gen., Chief of Engineers, U. S. Army.

[To be concluded.]

Mining and Metallurgical Section.

[Joint meeting of the Section and the American Institute of Mining Engineers, held Wednesday, May 14, 1902, at the Manufacturers' Club, Philadelphia.]

Steel Rails: Relations between Structure and Durability.

BY ROBERT JOB,
Chemist to the Philadelphia & Reading Railway Company.

(Concluded from p. 31)

DISCUSSION.

MR. JAMES E. YORK:—I have listened to Mr. Job's paper and noted his illustrations with much interest. The diagrams he has presented are very instructive as showing what a remarkable effect the physical treatment has on the wearing qualities of a steel rail. The present method of manufacturing steel rails, with their enormous output to-day, has evidently resulted in deteriorating the durability of the rail as compared with the rails made in the sixties and seventies. This might in a measure be explained by the fact that the rails then were of lighter section than now, and consequently received greater physical reduction, and also permitted of finishing at a lower temperature than at the present time; but this does not explain why the so-called John Brown rails, of which Mr. Job gave us illustrations, have shown such marked superiority over those of recent date, as regards actual service in the track. To explain this superiority we have certainly to look to the physical treatment of the rails. It may be of interest if I read what Mr. Robert W. Hunt writes in *Cassier's Magazine* on the chemical composition of the John Brown rails:

"* * * The carbon varied from 0.24 per cent. to 0.70 per cent.; silicon from 0.032 per cent. to 0.306 per cent.; phosphorus from 0.077 per cent. to 0.156 per cent.; sulphur from 0.050 per cent. to 0.155 per cent., and manganese from 0.312 per cent. to 1.046 per cent."

The great divergence in chemical composition of the rails made at that period compared with modern practice

makes it interesting to consider how these rails were then manufactured. In my own experience I remember that the rails between 1865 and 1870 were made by first casting a 14-inch ingot, of sufficient length and weight for three-rail lengths. These ingots were allowed to cool down and were then examined thoroughly for physical defects. After examination they were put into a heating furnace horizontally, and slowly brought up to the necessary temperature for manipulation, which consisted in bringing the ingot to the hammer and cutting it into three lengths. Two of the pieces were returned to the heating furnace for subsequent hammering, one piece being left for treatment at this initial heat. It was then hammered down to about 7 inches square and put on one side to cool, and again examined for any apparent surface defects. It was then carefully heated and to a lower heat than the primary heat, and rolled down into the finished rail. The reduction in rolling the rails was much lighter than in present practice, and consequently less severe on the structure of the material. This was necessary from the fact that the rolling mills of that period were much lighter, which necessitated lighter reduction. The rolls ran at much slower speed, permitting of the rolling at lower temperature, and the rails were, as Mr. Job has shown, satisfactory as regards wearing qualities. The output then was very small compared with that at present. It did not exceed 100 tons per day, whereas now 1,000 tons per day is not an unusual output. Then, too, these rails were sold at \$100 or more per ton; hence this apparently costly method was considered justified at that period and in those circumstances.

A short time ago I read in *The Iron Age* that Mr. Martin, of the Maryland Steel Company, considered that the desirable temperature at which rails should be finished to secure the best results as regards the fining of the grain in the head of the rail, was in the neighborhood of 700° C. to 750° C. I am inclined to think that there are mechanical objections to finishing at this temperature by the present method of rolling, from the fact that the physical structure of the rolls themselves would not stand such hard usage, and would

therefore necessitate frequent change of rolls. There are only two practical ways of physically fining the grain in steel mechanically; one is by hammering at comparatively low temperature and the other is by rolling at low temperature. The effects of cold-rolling have been clearly and practically shown by the experience of Jones & Laughlins in cold-rolled shafting, in which the tenacity, elasticity and resilience of steel is wonderfully increased, and this justifies my views on this matter, which are that it is necessary to finish rails in a specially constructed universal mill which permits of the use of chilled rolls—the only material in which steel, in any large quantity, can be rolled at any practical, desirable temperature. The present method of rolling is specially objectionable for rolling flange sections at a low temperature, from the fact that the difference in the delivery speed of the rolls on the various parts of the rail section makes it necessary that the temperature of the rail shall be such that the slower delivering parts can stretch or slip to accommodate themselves to the other parts of the section. Should this be attempted at a temperature of 700° C., the rail is liable to have permanent internal strains in the bar. This difficulty would be overcome by rolling universally, from the fact that every part of the bar is practically delivered at the same surface speed.

MR. MARTIN then arose and said, in regard to Mr. York's statement, that what he (Martin) had written was that he considered 750° C. a desirable temperature, and not that he had actually finished rails at that temperature. MR. YORK explained: I intended to say, Mr. Martin, that the temperature of 750° C. was what you considered desirable, and not that you had actually finished at that temperature.

MR. SIMON STROCK MARTIN (Maryland Steel Company, Sparrow's Point, Md.).—In Mr. York's reference to my article in *Iron Age*, of December, 1901, he erroneously uses the critical point temperatures of 750° C. steel as being temperatures that we have attained in finishing rails.

As to rolling at temperatures given, I wish to explain that these were obtained by the use of the water calorimeter, and this calorimeter checked with Le Chatelier pyrometer, and

would say we obtained temperatures as given, and get very good tonnages off sand rolls. We nevertheless use some chilled rolls, as he suggested should be done, and I know of other mills that use chilled rolls exclusively with results only slightly better than off sand rolls; and as with chilled rolls for rails, the tendency is for the deep collars to part from the body of the roll, on account of the unequal expansion of collar and body of roll, so much more so than with sand rolls.

MR. P. H. DUDLEY:—Mr. Job presents interesting and important matter for discussion.

His *Fig. 1* shows the characteristic microstructure of a number of modern rails which have worn rapidly under present service. The section shown in *Fig. 1* is evidently from the top rail of the ingot.

The mineral aggregates are large, exceeding $\frac{1}{100}$ of an inch diameter. Those forming the surface of the rail-head, under the weight of the wheel loads, break or shear and flow both in longitudinal and lateral directions. This is a characteristic form of wear under heavy service for all rails, though the rate is not as rapid with tough, fine-grained metal as rails of coarse structure. Near the surface of the head layers of the large mineral aggregates will break down to a depth of $\frac{1}{32}$ and sometimes as much as $\frac{1}{16}$ of an inch in depth, and then large portions of the metal become detached from the sides of the rail.

The structure shown in *Fig. 8*—while the polyhedrons are as large or even larger than that shown in *Fig. 1*—is a different structure and has much greater tenacity, though in the surface of the head the mineral aggregates will break down by shearing under the wheel treads, but not as rapidly as that shown in *Fig. 1*.

One of the important features of Mr. Job's paper is that relating to excess of foreign matter—oxides, slag and enclosed gas, represented by *Fig. 2*. Such matter in excess in the metal renders the ingot or a portion of it unsound, which is not always remedied by cropping the bloom.

The larger ingots having a smaller percentage of columnar structure than the former small ingots, the metal shows

wear quickly in the present heavy rails under the heavy wheel loads. The seams in the head of the rail (*Fig. 12*) are due to the excess of foreign matter. The breaking down of the surface of the head of the rails with great rapidity under the present wheel loads shows most rapidly in the top rail of the ingot, which, as a rule, contains the largest percentage of foreign matter.

Regarding the Differences of Structure in Rails.—The finer structure shown in *Fig. 3* gives a better wearing body than that shown in *Fig. 1* or even *Fig. 8*. The layers of mineral aggregates break down by shearing under the wheel treads, the depth rarely extends below the surface over $\frac{1}{32}$ of an inch, a less depth being more common for the center of the rail-head. The structure shown in *Fig. 6* belongs to rails which were manufactured many years ago from small ingots, and were allowed to cool and then reheated before they were hammered into blooms.

I have never been able to obtain a similar structure to that shown in *Fig. 6* from any of our modern rails, even when rolled down to small sections until the rails were barely red. Some of the specimens from older rails which were hammered have shown nearly a similar structure. The rails from the hammered blooms had from 18 to 20 passes in the different trains before the rail was finished; each reduction was very light and the trains were run at moderate speeds. The capacity of the mills averaged from 60,000 to 70,000 tons per year. Those rails which were imported cost from \$120 to \$140 per ton in gold, and while they have rendered exceptionally good wear, the small mechanical element of stiffness of the sections compared to their weight only enabled very light axle loads to be carried over them. The number of cross-ties which those rails have required would more than have covered the cost of stiffer rails, and while they could be used in yards where the train movement was very slow, yet out on the main line they have long been too light to be economical.

As to the influence of mill methods upon the size of grain, a number of observations have been recently made on the rails rolled by holding before the finishing pass,

which show more reduction in structure than is indicated by even *Fig. 5*. The comparative wear must be ascertained by actual service.

The steel in the modern rails is now of much greater tensile strength and higher elastic limits than in the rails which were rolled twenty-five and thirty years ago. The higher physical properties can be obtained by proper care without producing brittleness. The form of the sections now is much better adapted to the higher physical properties of the steel than those formerly in use. Their fracture in the track is not nearly so dangerous as in the lighter sections.

Fig. 8 represents structure at center of head of rail which has stood the drop-test, while *Fig. 10* represents structure of a section of the same rail which has been reheated to cherry red and let cool at once in the air. The tensile strength is increased apparently 1,100 pounds per square inch, while the elongation and reduction of area have also increased. Such rails ought to give an increased wear from the fact that the mineral aggregates are so much smaller than the coarser grains shown in *Figs. 1* and *8*. As a girder we depend upon the linear elongation for the modulus of elasticity, while for sustaining the wheel loads upon the surface of the girder we depend more upon the cubic elasticity, or elasticity of volume.

The small grains have a higher cubic elasticity than the coarser grains, the latter failing directly by shearing under the wheel contacts.

That foreign matter in steel lowers the tensile strength, elongation and reduction of area, and in addition tends to brittleness, and that when present in fair excess with high finishing temperature it renders the rails fragile under the drop-test, is true without any question.

The statement that the presence of a relatively large proportion of foreign matter may not produce brittleness, provided the grain of the steel is fine, is true, so far as the longitudinal elasticity is concerned, but for the cubic elasticity, foreign matter permits the head of the rail to crush and deteriorate rapidly under the wheel loads.

In general it is true that to ensure the most desirable rail of a given composition, service tests prove that there must be absence of brittleness and freedom from foreign matter, and presence of fine granular structure. Absence of brittleness is indicated by ability to withstand the drop-test of 2,000 pounds falling 20 feet; that means that the section of rail must be able to take up 40,000 foot-pounds of energy without fracture. This will produce a compression of the metal in the head for a limited length; also an extension of the metal in the base. With a section 5 inches high, a deflection with decided elastic reaction will be produced. If the supports are 3 feet apart, the permanent set for a high-grade rail will be from $1\frac{3}{4}$ to 2 inches. The metal in the head of the rail directly under the drop will have a maximum compression of 5 to 6 per cent., and the metal in the base of the rail will have a maximum extension of 5 to 6 per cent. The metal in the head of the rail will be compressed for a length of 10 to 12 inches, and the base of the rail will be extended for 10 to 12 inches. The width of the head will be widened, while that of the base will be narrowed and thinned down. If the rail is 6 inches in depth, then the same energy, while it will produce almost the same extension or compression of the metal per inch, does not produce as great deflection, the permanent set being about one-half that of the 5-inch section for the same high grade of steel.

On the hypothesis that fine granular structure is ensured by stipulating that the temperature of the ingot or bloom shall be such that with rapid rolling, and without holding before or in the finishing passes or subsequently, and without artificial cooling after the last pass, the distance between hot saws shall not exceed 30 feet $5\frac{1}{2}$ inches for a 30-foot rail (90 pounds), or a proportionate distance for other lengths, it does not appear that Mr. Job has given sufficient consideration to the increased speed and reduction, nor the number of heat units to be dissipated in the large ingots at present in use as compared to the smaller ingots, slower train speeds, lighter reductions, less number of heat units, of the early steel rails. While the cooler rolling of the

metal will improve the quality, it is not all that is required to make good rails for present service. It has now been found by examination, that with the great reduction in the passes and rapid rolling, the metal is often injured and partially separated, so that it develops a weakness afterwards in the finished rail, the ingots having been perfectly sound before rolling.

MR. WM. KENT:—The older members of the Institute of Mining Engineers remember the famous discussions over twenty years ago on the papers of Dr. Chas. B. Dudley, on the wearing power of steel rails. In these papers it was attempted to show what was the relation of the wearing power to the chemical composition and to the physical properties as far as the latter could be determined by the ordinary testing machines. The results of the discussion left the problem an unsolved one, but they showed that the wearing power must depend on something besides the chemical composition—something of which nothing was definitely known at that time. Twenty years ago we knew practically nothing about the microstructure of steel, or about the effect of heat treatment on that structure. Meantime, the manufacture of rails has developed by a tentative method. It has been found necessary to raise the carbon as the weight of the rail has increased, and something has been learned in regard to the amount of work that should be put on an ingot and the temperature at which it should be finished. Mr. Job's paper is the first attempt in over twenty years to put our knowledge of the subject on a scientific basis. It shows not only the relation of wearing power to microstructure, but also how the most desirable microstructure may be obtained. Mr. Job is to be congratulated upon his most important scientific research, and upon his having laid the foundation for much further research in the same direction.

MR. JOB:—Regarding Mr. York's remarks concerning the cause of the durability of the old rails of light section, it has been previously stated that the process then in vogue necessitated thorough working of the steel well down toward the critical temperature. This resulted in the very

fine-grained structure shown in *Fig. 6*, and as a consequence the ductility was far greater than is attained in the practice of to-day with the same composition and the same weight of section, but when the thorough working of the steel is stopped at a higher temperature. In *Figs. 8* and *10* we have seen that the fining of the grain has resulted in a marked increase in ductility and reduction of area, with increased strength, and, as has been shown, we know from service results that such changes with any given composition result in greater durability in actual track service. Thus, the cause of the superiority of the old rails is fully accounted for by the betterments shown in their physical qualities.

In Mr. P. H. Dudley's interesting discussion it is noted that sufficient consideration does not appear to have been given to the increased speed and other conditions of present mill practice, and that, while the cooler rolling of the metal will improve the quality, it is not all that is required to make good rails for present service, since the metal may be injured and partially separated by great reduction in the passes. In the paper I have stated that fine granular form is greatly desired, but that this is only one of several essentials required to effect durability in service. In the cases of separation of the metal mentioned, brittleness would result and would be detected by the drop-test. It is understood that proper mill methods shall be used throughout the process of manufacture, and where this is done we do not find evidences of brittleness.

PETROLEUM DEPOSITS IN MEXICO.

Consul Griffiths at Matamoros reports to the State Department that in view of the scarcity of fuel in Mexico, the exploration and exploitation of oil lands is attracting considerable attention in that country. The recent discoveries at Beaumont, Tex., have given rise to the hope that oil in paying quantities will also be found in Mexico. Very favorable indications of its presence have been discovered at several places, and liberal concessions for the development of petroleum deposits on national lands have recently been granted by the Federal Government to prospectors.

Almost certain indications of the existence of petroleum are to be seen in

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many States, and especially in Tamaulipas, where in places there is an abundance of asphalt, sulphur and oil on the surface. Besides these signs, some of the topographical features, according to the opinion of an expert engineer and oil prospector, are due to the great pressure of the confined natural gas beneath. In most cases, the exudation does not consist of any one substance in a paying quantity, but passes through all the grades, from an inferior, dark-colored oil to massive hard asphaltum rock. There are also other equally encouraging indications of an abundance of gas and oil in the shale below.—*Engineering and Mining Journal*.

THE ARTIFICIAL PRODUCTION OF PRECIOUS METALS.

For over a thousand years mankind declared and believed that gold and silver could be artificially produced, and innumerable searchers have labored on this problem. These workers have not been wholly within the class of metallurgists or what we might call scientists, but all ranks and callings have contributed contingents. The general impulse which we designate as alchemy remained influential until the beginning of the eighteenth century, and was so widespread that it deserves consideration by a student of social science. While it is probable that in the more ignorant ages a larger number of persons believed in incantations and ghosts than practised true alchemy, yet the public profession of the latter was much more frequent than the public profession of supernatural powers. The history of alchemy has indeed less significance for chemistry than for the history of culture.

The belief in transmutation was promoted by the observation of cases in which the appearance of gold and silver could be imparted to baser metals. For example, copper alloyed with zinc assumes the ordinary color of gold. Treated with certain arsenical substances it assumes a silverlike appearance. Moreover, the doctrine of Aristotle, that substances differ not because of different composition, but by reason of difference of properties, necessarily encouraged the transmutationists. It was in this spirit that one operator distilled mercury seventeen hundred successive times in hopes of driving out from it the liquefying principle and thus obtaining the solid silver.

The ignorance as to the details of chemical composition also led to another misunderstanding. Mine waters containing copper compounds (the existence of copper as such in the water was not recognized) would, by the action of iron, deposit the copper and the iron would dissolve. We have no difficulty to-day in comprehending the nature of the action, but there was a time when it was believed to be transmutation, and in alchemical language was expressed as being due to Mars (iron) having laid off his armor and decorated himself with the garments of Venus (copper).

It is interesting to note also that, according to the Greek alchemists, lead was the generator of other metals. It was especially the generator of silver. We have no difficulty in understanding how this last error arose. Lead ores usually contain some silver, often very considerable amounts, and the operation of cupellation easily burns off the lead and leaves the button of silver, in which small amounts of gold are often found.—Henry Leffmann, in *Cassier's Magazine*.

Mining and Metallurgical Section.

Read at the Stated Meeting, held Wednesday, December 11, 1901.

Upon the Structure of Metals and Binary Alloys.

BY WILLIAM CAMPBELL, B.Sc. (Durham), F.G.S.

(Continued from p. 16.)

Fig. 10 shows the surface-structure of a bar of aluminium. Two intersecting dendrites are seen. In each only one quadrant has developed. We have two axes at 90° , and from each grow parallel branches normal to their own axis, but parallel to the adjacent axis. From these branches grow leaf-like grains, thus forming a true skeleton crystal. The whole shows a decided cubic character. The cubic structure of aluminium can be clearly shown by casting a small ingot of the metal. When half solid, the ingot is tilted and the liquid part is allowed to drain off. The rough surface thus exposed is seen to be divided up into many areas; each area is made up of a number of small cubes similarly orientated, whilst each cube is made up of row upon row of minute grains. The whole structure resembles a surface of silicon steel ($4\frac{1}{2}$ per cent.) in Stead's Crystalline Structure of Iron and Steel.*

Copper, platinum, gold and silver show this dendritic structure on their surfaces when suitably cooled. *Fig. 11* shows the structure met with on the surface of a cupellation button of silver. Only the center of the skeleton crystal is shown, but the two main axes can be seen at right angles to each other; from each grow out, normally, parallel rows or branches composed of grains. The nearer to the center of crystallization, the smaller are the grains. In *Fig. 12* a smaller skeleton crystal is shown. It is similar to the large ones, but is stunted in growth. It shows the curious growth at the ends of the axes where they merge into the

* *Iron and Steel Institute*, May, 1898.

surrounding surface. Although these skeleton crystals are fairly common, they do not occur on all silver buttons. The normal structure of the surface of a cupellation button of silver is shown in *Fig. 13*. It consists of grains with straight boundaries. This structure is probably the result of contraction on solidification, because, in places, the lines are seen to cut across patches of similar orientation, *i. e.*, crystals. The true area of each grain (crystal) is seen by its orientation, and the lines of fissure generally coincide with the true grain (crystal) boundary because these will be the lines of weakness. In some cases, however, they take a direction of their own. This cooling structure is probably similar to that met with in many basalts. The surface structure of a silver ingot is seen in *Fig. 14*. There are several large grains or crystals with irregular boundaries but distinct orientation, each made up of secondary grains, similarly arranged, causing that orientation.

In the case of bismuth, *Fig. 15*, we see that the dendrites are inclined to assume a definite crystalline form; and this is exactly what we should expect when we remember the definite forms seen on a crust from a crucible of bismuth. The stars of antimony are too well known to require any description here.

When certain metals are cast, dendrites are formed by the shrinking of the liquid part during solidification, thus leaving them standing above the surface. A similar thing occurs when many alloys are cast. We may have dendrites of a metal left in relief, due to the shrinking of the eutectic or portion of the alloy which solidifies last; or we may have definite crystals, generally of a compound, standing up above the surface. These surface structures, as we said before, are often very reliable indications of the internal structure of the alloy. They may also be very misleading, however, as in the case of the bronzes between 70 per cent. and 95 per cent. of copper.

In his paper on the "Crystalline Structure of Iron and Steel,"* Stead points out that the same law which deter-

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mines the size of the individual crystals formed when hot saturated solutions of chemical salts are cooled quickly or slowly holds good when metals solidify from the liquid state. If a metal be cooled very slowly past its freezing point, its structure will be comparatively large; if it be cooled rapidly past its freezing point, the result will be a much finer or more minute structure. In cooling slowly, crystals start to grow from a comparatively few points only, and the resulting structure is large; in rapid cooling, the points of initial crystallization are numerous, and the structure on complete solidification is small. When a crystal starts from a point it grows in all directions till interfered with by the growth of adjacent crystals. As the crystals seldom grow so that their crystallographic axes lie in the same directions, we find on solidification that each has a different orientation. This difference in orientation is beautifully seen if we take ingots of lead, tin, cadmium, zinc, etc., and lightly etch their surfaces. The effect of etching is to take off the surface of the metal, but not as a film of uniform thickness. The acid has not the same effect on each crystal, but removes more of one than of another, the amount depending upon the position of the crystal with relation to the surface which is being etched. The acid follows the track of the secondary crystals, or rather grains, and so we have a step-like surface eroded, which resembles, more or less, a broken surface of galena. Thus, light is more or less reflected from each crystal, depending on the angle at which the step-like surface is inclined.

The size of the crystals of an ingot of metal and, to a great degree, their shape depend upon the mould in which the metal is cast. Thus tin, when cast in a stone mould, gives quite a different appearance to what it does when cast in iron; the difference, of course, being due to the difference in rate of cooling. Again, the size of grain or crystals depends upon the purity of the metal used. If pure and impure tin be cast in the same mould, in the case of the impure tin the crystals will be comparatively long and slender, their length pointing towards the axis of the ingot.

The fractures of ingots in general reveal a columnar

structure. If an ingot of zinc be broken, elongated crystals with irregular faces are seen to have grown from the surface next to the mould perpendicularly towards the center of the ingot. If a section of an ingot of lead or tin be cut vertically, polished and etched, a similar structure is seen. If ingots of lead are broken hot, this columnar structure is beautifully revealed, whilst cast cylindrical rods of most metals show a radial structure, due to the same cause. On fracturing a cast rod of antimony the structure is that of numerous elongated pyramids with their apices meeting at the axis of the rod, their bases forming the cylindrical surface of the rod.

THE EFFECTS OF STRAIN.

The effects of strain upon metals has been well explained and illustrated microscopically by Ewing and Rosenhain.* Charpy† has illustrated the effects of strain and also of annealing upon the brasses, etc.; Roberts-Austen‡ upon steel rails and gun tubes.

Ewing and Rosenhain state that no effects of strain can be detected under the microscope within the elastic limit; but as soon as this is passed, fine dark lines are seen on the faces of the grains. They are more or less straight, are parallel in each grain, but are differently orientated in different grains. The first lines that appear are those approximately transverse to the line of force; but as the force increases, other systems of lines appear on other grains, and these lines are inclined to the direction of straining. As the straining increases some of the grains begin to show one, two, three and more systems of parallel lines, thus giving the grain the appearance of Schillerization. If the surface of a bar of bismuth, which has been strained till it broke, be examined, the lines or slip-bands are clearly seen on each side of the fissure. Several parallel groups will appear in view. *Fig. 6* in Dr. Mathews' paper showed some of these

* Bakerian Lecture, May 18, 1899, *Phil. Trans. Royal Soc.*, cxciii, p. 353.

† *Bull. de la Soc. d'Encouragement*.

‡ *Journal Iron and Steel Institute*, No. II, 1898; No. II, 1900.

slip-bands in tin. It shows the strained surface of an ingot of pure tin, whilst *Fig. 5* of the same paper showed lines of strain set up in a section of tin which had been hammered and then annealed. Similar slip-bands in crystals of cadmium are shown in *Fig. 8*. The cry of tin, the crackling of zinc, etc., are due entirely to the formation of these slip-bands.

It was mentioned above that when a soft metal, such as lead or tin, was cut with a file, particles tend to cling to the file and tear the surface of the metal. A similar thing happens with nearly all the softer alloys. The immediate effect is not noticed; but on etching, long parallel lines of irregular grains or crystals are seen to have been developed. *Fig. 3* shows such lines developed in tin. When a soft metal or alloy is cut with a saw, a similar crystallization is set up, and unless the metal thus modified is removed during subsequent treatment, this crystallization appears along with the original structure on etching. *Fig. 4* shows a section of slowly cooled tin which has been cut with a saw; a finer crystallization is seen together with the larger structure, due to the original cooling. If etching be prolonged the finer structure is obliterated, showing that it is only on the surface.

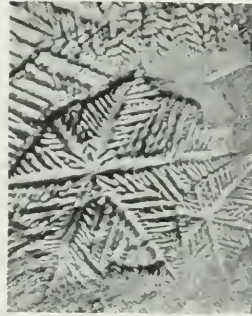
Now, when a piece of metal is hammered or rolled the crystals become lengthened in the direction in which it has become drawn out, and shortened in the direction of contraction. In the case of copper, iron and other of the tougher metals, this attenuating stage is of comparatively long duration; but in the case of the softer metals it is short and the crystals or grains break up to form a new and minute crystallization. *Fig. 2* of Dr. Mathews' paper shows the appearance of hammered tin. The structure is roughly granular and no trace of the original slow-cooling structure can be seen as in *Fig. 4*. Rolled tin has a similar structure, and it is curious to note that the thinner the piece is rolled the more distinct become the individual crystals. At a certain point they no longer split up, but become attenuated as if plastic. The structure of rolled cadmium is shown in *Fig. 6*.

THE EFFECT OF HEAT-TREATMENT.

It is well known that annealing tends to relieve the strain in a metal or alloy. In many metals it does more than this; it causes the growth of crystals or grains. *Fig. 1* of Dr. Mathews' paper shows a bar of tin rolled out to about 3·5 millimeters thick. The right-hand pair show the structure of the metal just as it comes from the rolls. The left-hand pair have been annealed for ten days upon a hot-plate at not more than 180° C. The size is slightly reduced. The difference between the unannealed and the annealed specimens is striking to say the least. The orientation in the left-hand pair is marked and shows the boundaries between the various crystals. *Figs. 3* and *4* of the same paper show hammered tin unannealed and annealed at about 180° C. for seven days on a hot-plate (not ten days as stated). Again the difference between the two specimens is striking. In *Fig. 4* it will be noticed that the new crystals tend towards straight regular boundaries and in section are more or less perfect hexagons.

Fig. 5 shows five pairs of strips of cadmium rolled out from a rod. Starting from the right, the first pair have a thickness of 0·075 inch, the second of 0·049 inch, the third of 0·036 inch, the fourth of 0·024 inch, whilst the last and thinnest pair are only 0·018 inch in thickness. They were rolled out from a rod having a circular section $\frac{5}{16}$ inch in diameter. Their length is $2\frac{3}{8}$ inches and breadth 0·4 to 0·45 inch.

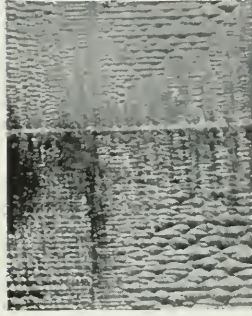
The right-hand strip of each pair has been annealed for seven days in an air bath at a temperature under 180° C. Etching in all cases was with nitric acid dilute. After rolling, the thickest pair (No. 1) were found to have the coarsest structure and this is shown in *Fig. 6*. After annealing, although tolerably large crystals were found in all of the strips, the thickest strip was found to have the coarsest average grain. *Fig. 7* shows the crystals developed in No. 3 by annealing. The definite boundaries and distinct orientation are to be noted. Those developed in No. 1 were so large that a single crystal would cover the whole figure at the same magnification, whilst those developed in the thin-



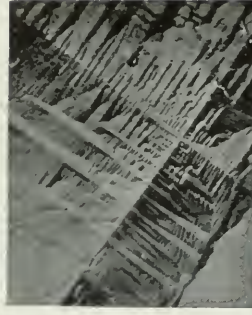
9. x 33. v.



10. x 33. v.



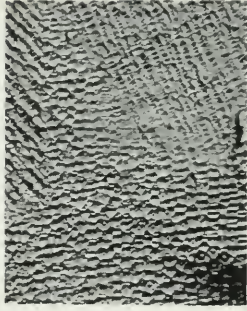
11. x 33. v.



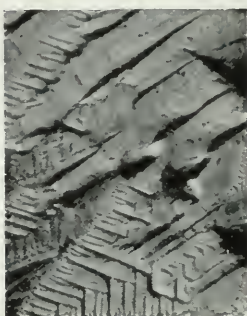
12. x 33. v.



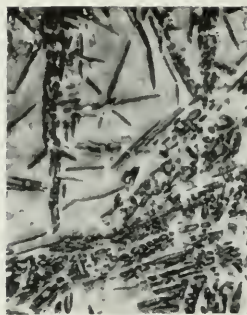
13. x 16. v.



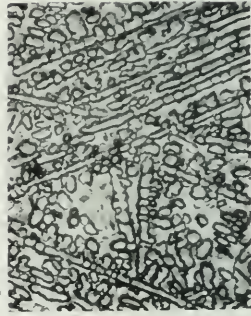
14. x 33. v.



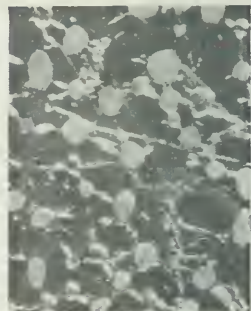
15. x 33. o.



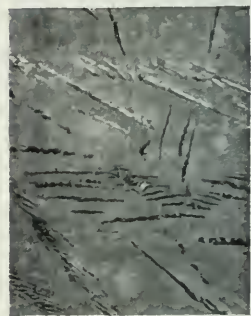
16. x 33. v.



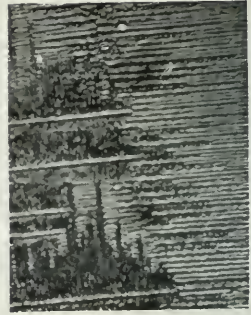
17. x 33. v.



18. x 33. o.



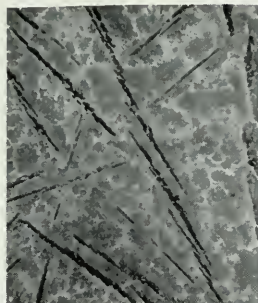
19. x 33. o.



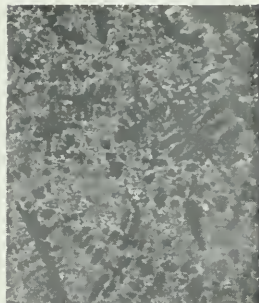
20. x 33. v.



21. x 56. o.



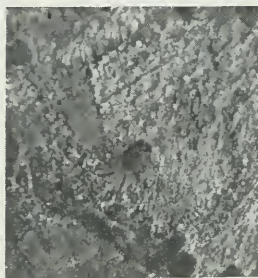
22. x 33. o.



23. x 33. v.



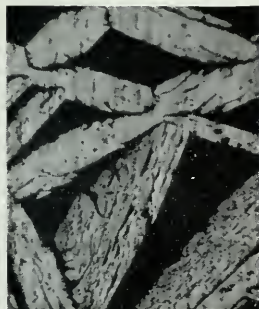
24. x 30. v.



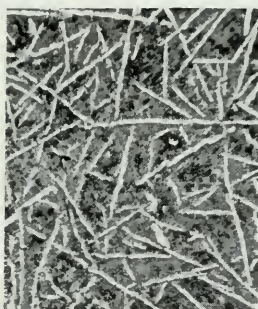
25. x 56. o.



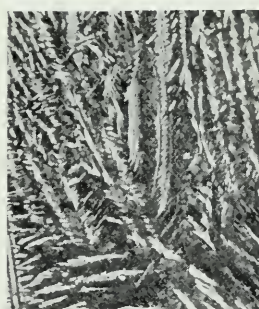
26. x 33. v.



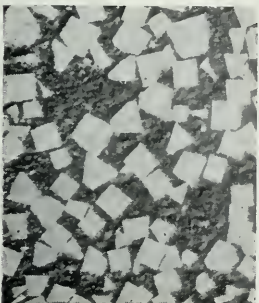
27. x 33. o.



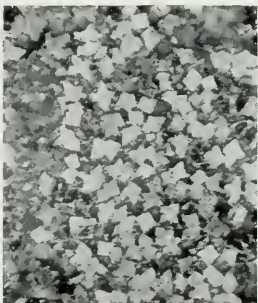
28. x 33. v.



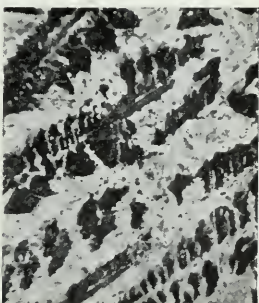
29. x 16. v.



30. x 33. v.



31. x 33. v.



32. x 16. o.

nest strip were proportionately smaller. *Fig. 8* shows some of the smaller grains or crystals of No. 1, photographed after the strip had been bent. The strain produced by bending has set up the series of slip-bands. Five distinct parallel series can be seen in the largest grain on the left.

An exactly similar experiment was performed with tin. The annealing was carried on for five days on a hot-plate and the results were identical with those of the cadmium. In both cadmium and tin, annealing produces a marked brittleness, and when the strips are distorted they cry.

If ordinary rolled sheet lead be etched and examined, a structure similar to *Fig. 6* will be met with. Etching is best performed with acetic acid for a long period. Anneal it for a week at a temperature of only 200° C., and a coarse, very irregular crystalline structure will be developed. The crystals will be of all sizes and shapes; in many, distinct twinning will be observed. In all cases the difference in orientation will be marked. In one case a crystal quite 1 inch long by $\frac{1}{2}$ inch in breadth was grown in five days by the author. The temperature was only 180° C. and the thickness of the sheet of lead 1.75 millimeters.

Take zinc and roll it out into strips; it will take a fairly high power to reveal its structure. Anneal it as before shown and you will find the crystals have grown so large that some two dozen will be all that are able to occupy your strip. The rolled zinc will be exceedingly tough, but after annealing it will crackle on bending ever so slightly and will break if further bent, for annealing has made it extremely brittle. On slightly bending it and then examining it under the microscope, it will be seen that each grain is traversed by parallel systems of slip-bands, which develop into cracks if the bending be carried to any considerable extent.

If the surface of electrolytically deposited copper be examined, a coarse crystalline structure is seen. On parts of the sheet it will often be found that the rate of deposition has been greater than the surrounding surface and a crystalline knob of copper stands out above the level of the rest of the sheet. If a section be made through one of

these knobs, and the surface be polished and etched, the true crystalline structure is shown up. It consists of comparatively large, irregular crystals, each possessing a definite orientation. If this copper be rolled out, the large crystals are broken up and a much finer crystallization is set up, still composed of crystals with irregular boundaries. If copper foil be examined after its repeated annealing and rolling, or rolling alone, it is seen to be composed of very small grains. The foil possesses a marked amount of spring. No amount of etching will show any orientation and the structure seems to be composed entirely of oval grains, pointing, of course, in the direction of rolling. It is similar to that of sheet-copper which has been rolled out from an ingot. Anneal it for a moment at a straw heat and it becomes quite limp with no trace of spring left. On examination the fine crystalline structure has disappeared and a large mottled structure is now seen. Thus there is an intimate relation between the fine rounded or oval-grained structure and elasticity of the copper foil.

Electro-nickel when polished and etched shows a reniform structure where it has formed a knob-like mass. Numerous distinct layers can be seen, but, so far, no distinctly crystalline structure can be seen. The structure of iron appears to be similar to that of nickel, that is, it consists of layer upon layer like an agate. The effects of annealing and rolling electro-nickel and iron have not been examined as yet by the author.

The growth of crystals in the solid due to annealing has been shown over and over again. Roberts-Austen, in his last Cantor Lectures, delivered to the Society of Arts, London, exhibited three photomicrographs showing the growth of crystals in pure gold. The first showed two plates of pure gold pressed together. The squeezing was so great that the crystals had been strained. Without strain, it is thought that no welding will take place. The second view showed the plates after annealing at 750° C. and slowly cooling. The junction between the two plates could be distinguished, but in several places crystals had grown across the junction. A third view showed the same after long

annealing and the line of junction had entirely disappeared. If a section be taken across a weld in a steel rail or bar which has been joined by the Goldschmid welding process, no line of junction can be seen.

ALLOYS.

Under the heading of "Alloys as Solutions," Dr. Mathews points out that certain metals when liquid at ordinary temperatures do not mix or alloy, and on standing separate into two layers, the heavier at the base.

The following are some of Dr. Alder Wright's figures, obtained by taking each of the five pairs well mixed by stirring, and then allowing them to stand molten for some hours at 800° C.; separation took place; two liquid alloys were formed; these were quenched and each analyzed.

In the case of zinc and lead, the heavier alloy contained 1.3 per cent. Zn; the lighter 1.57 per cent. of Pb.

In the case of zinc and bismuth, the heavier alloy contained 14.28 per cent. Zn; the lighter 2.32 per cent. of Bi.

In the case of aluminium and lead, the heavier alloy contained 0.07 per cent. Al; the lighter 1.91 per cent. of Pb.

In the case of aluminium and bismuth, the heavier alloy contained 0.28 per cent. Al; the lighter 2.02 per cent. Bi.

In the case of aluminium and cadmium, the heavier alloy contained 0.22 per cent. Al; the lighter 3.39 per cent. Cd.

If we allow our molten metal to cool down very slowly till it solidifies, and then examine the two alloys thus formed, in the case of zinc and lead or aluminium and lead, and most probably also of aluminium and bismuth or aluminium and cadmium, we get the same results. Each alloy is a solid solution of one metal in the other; no crystals but those of the metal in excess can be seen. Take the aluminium-cadmium pair. The structure of the upper part is that of aluminium, and all of the cadmium it contains is in solid solution. The structure of the base is that of cadmium, and all the aluminium in it is in solid solution. In the case of the lower alloy of the lead-aluminium pair, it is probable that the lead throws all of the aluminium out of solution before solidification, because, according to

Heycock and Neville, the freezing point is not depressed at all.

With the zinc-bismuth pair matters are different. The upper alloy shows zinc containing all the bismuth in solid solution, but the lower one shows a fine crop of crystals in a groundmass, which is probably a eutectic of bismuth and zinc, as is shown in *Fig. 16*. Thus between bismuth and about 13 per cent. Zn, 87 per cent. bismuth, we get one layer in each alloy we make. Between these points we have a simple series of alloys, whose freezing-point curve consists of two branches inclined to each other and meeting at the eutectic point 3.5 per cent. Zn at about 240° C.*

If either of the five pairs of metals above be melted and a sufficient proportion of either tin, silver, antimony or copper be added, no separation will take place; but if the quantity of the "solvent" metal is less than a certain amount, the alloy separates into two layers, each layer consisting of a ternary alloy of the three metals. *Fig. 17* shows a case where sufficient of the "solvent" metal was added and a single ternary alloy was formed. The alloy consists of equal weights of zinc, bismuth and tin. The figure shows long dendrites, which closely resemble those of zinc in zinc-tin alloys, set in a groundmass, probably a triple eutectic of BiZnSn.

In many text-books the amounts which each of the above pairs of metals retain of the other when solid varies widely. In some cases we are told that aluminium mixes freely with both bismuth and cadmium. The reason for this lies in the method of cooling. If instead of cooling slowly we cast or chill our alloy, directly after stirring, we don't allow our emulsion to settle, and in consequence *globules* of the heavier are found in the lighter alloy. *Fig. 18* shows the surface of aluminium containing such globules. Aluminium was melted with some Bi and Cd. When thoroughly melted the pot was shaken and the alloy poured into a cold iron mould. In consequence of the rapid cooling, separation

* Gautier: *Bull. de la Soc. d'Enc.*, Vol. I, 1896, p. 1293. Roberts-Austen: "Introduction to Metallurgy," plate pp. 114-115.

could not take place, and scattered throughout our aluminium appear shots or globules of the bismuth-cadmium alloy. When slowly cooled perfect separation took place.

BINARY ALLOYS.

Charpy* has published one of the most complete papers on the microstructure of binary alloys. He classes them according to their curves of fusibility, following Le Chatelier.

Group I.—Two branches of curves starting from the melting-points of the two pure metals and meeting at a point corresponding to the eutectic alloy; this curve is obtained when the metals form neither definite compounds nor isomorphous mixtures.

Group II.—Three branches of curves, two of them starting from the melting-points of the pure metals and a third exhibiting a maximum and crossing the two former in two points corresponding to two eutectics; it is the case of two metals forming a definite combination.

Group III.—The curve of fusibility is continuous and unites the melting-points of the two metals forming isomorphous mixtures.

Fig. 14 in Dr. Mathews' paper shows types of these curves. Group I is represented by the AgCu curve, Group II by the SbCu curve, and Group III by the AuAg curve.

To Group I belong all those alloys in which the excess of either metal crystallizes out in a eutectic which is a mechanical mixture of the two metals.

Tin and zinc.

Tin and lead.

Tin and bismuth.

Lead and antimony.

Lead and silver.

Zinc and aluminium.

Copper and silver.

Copper and gold.

Dr. Mathews' explanation of *Fig. 18* of his paper holds good in the case of all the above alloys, the only difference being that in some cases the compositions *b* and *d* represent comparatively large figures, as for example in the case of copper and silver or copper and gold; in some cases *b* and *d* represent compositions of solid solutions infinitely dilute;

* *Bull. Soc. d'Encourag.*, March, 1897.

that is, b and d are numerically very small, as in the case of tin and zinc, etc.

We can form a sub-group in which the excess of one metal crystallizes out in a eutectic which is a solid solution of this metal in the second.

Aluminium and tin.

In Group II we get two divisions for each pair of metals alloyed, each division being comparable with Group I, thus:

(1) The excess of the first metal or the compound crystallizes out in a eutectic which is a mechanical mixture of this metal and the compound.

(2) The excess of the second metal or the compound crystallizes out in the second eutectic, which is a mechanical mixture of the second metal and the compound.

Copper and antimony.

Tin and nickel.

A sub-group might be formed in which the eutectics are solid solutions of the compound in either the first or the second metals.

Antimony and aluminium.

Thus we get two divisions, each of which is comparable with the sub-group of Group I. In the case of antimony and aluminium we have the compound SbAl crystallizing out in a eutectic which is a solid solution of Sb in Al, or in a eutectic which is a solid solution of Al in Sb.

[To be concluded.]

ARC LAMP CARBIDE ELECTRODES.

A patent granted May 20th to Robert Hopfelt, of Berlin, Germany, describes several forms of a new type of electrode for arc lamps. In each case the material of the electrode consists of calcic carbide, coated with a water-proof compound or sheathed with a metal such as aluminum. It is stated that metallic carbides, such as calcium carbide, gives a much more powerful arc than do ordinary carbon electrodes, but that this material has not been employed in arc lighting heretofore because of the decomposition incident to the presence of moisture in the air. By covering the surface of the carbide with a layer impervious to moisture, it is claimed that this objection is obviated. In another form of the electrode there is a cone of metallic wire, and in still another form, a core of carbon dust. A solid electrode is also described, consisting of a mixture of carbon and carbide.—*Electrical World*.

Mining and Metallurgical Section.

[Joint meeting of the Section and the American Institute of Mining Engineers, held Wednesday, May 14, 1902, at the Manufacturers' Club, Philadelphia.]

The Beaumont Oil Field, with Notes on Other Oil Fields of the Texas Region.

BY ROBERT T. HILL, Washington, D. C.

INTRODUCTORY.

The successful completion, January 10, 1901, by Capt. A. F. Lucas, of a well near Beaumont, Tex., whereby an enormous flow, estimated at 75,000 barrels a day, was obtained, opened a new oil-field in the United States, kindled a frenzy of exploitation and speculation, revolutionized the fuel industry of a large region, and brought gain to thousands of people.

Even to-day, it is impossible to cast up the present results or to prognosticate the future influence of this event. It has caused the revival of attention in other localities where oil had been suspected and exploitation for oil throughout the Texas region. It has attracted attention to the mineral resources of the Texas region, and created an interest in the geological conditions of that great State.

This State, which has increased in population and wealth, as recorded by every succeeding census, with leaps and bounds such as are exhibited by no other part of the Union, now stands fifth in population and first in productive wealth *per capita*. Its fields, pastures, forests and mines teem with raw material. The whole economic evolution of the State has gravitated toward a focal point where these products were available for the coming of the kiln, the machine and the factory.

The only drawback to the prosperity of the State was the lack of an economic fuel, inferior coal costing an aver-

age of \$5 per ton at the time of the Beaumont discovery. This prevented the successful operation of any one of the thousands of minor industries upon which other communities ordinarily depend for prosperity. As by a touch of magic, this great fuel supply burst forth in a single day, thanks to Captain Lucas, who, aided by the wise laws of the railway commission, placed at the fireside of every citizen, at every quarry, clay-bank, sandpile, mine and mill, the cheapest and best of fuels.

With these factors in hand, who can even grasp the significance of the great industrial development which is to take place within that empire during the next decade? Who can conceive the countless wheels to be set in motion? Who can reckon the prospective increase in population, the municipal development, the opening of brickyards, factories, shops and mills? Never before in history has there been such a culmination; never again will such opportunities be presented for the man of energy as means are now presented in Texas.

THE LIMITATIONS OF GEOLOGICAL INTERPRETATION OF OIL-PHENOMENA.

In endeavoring to interpret the geological occurrence of oil, the geologist is confronted by the fact that science has not yet solved the problem of its origin, which lies at the root of the subject.

Among the theories in this field are those of inorganic chemical origin, resulting from reaction of one mineral upon another; the generation of oil in living microscopic organisms, such as diatoms; and the generation of oil from the decomposition and deterioration of dead organic matter, animal or vegetal, preserved in the rocks. There are facts in nature which can be made to conform to either of these theories; but for the present we must consider oil as a material in the rocks, the origin of which is still unexplained.

Concerning this occurrence, we can only say that each field where it is discovered presents a peculiar group of data, some of which may, or may not, be presented in others.

It is well known that certain strata, like shales, with large admixture of organic matter, are nearly always more or less bituminous, and are probably the *locus* of the original formation of oil from decomposition of the organic matter. On the other hand, the oil in commercial quantities is usually found in some adjacent bed, like an overlying stratum of sand, which forms a more porous receptacle. Where such shales and sands are in proximity, the oil is practically indigenous; and such occurrences may be termed sheet-oil. In other cases, oil is found in pockets, in strata which do not contain sufficient bituminous matter to justify the reference of its origin to them. Such occurrences may be termed pocket-oil.

Science has ascertained much concerning the underground circulation of water, but we know very little concerning the laws controlling the underground circulation of oil. The few elementary physical facts concerning the behavior of oil and water teach us some lessons. From the antithetic behavior of the water and the oil upon the surface, we can with safety presume that these substances will not act in an entirely harmonious manner underground. We know that oil will float upon water, and therefore that circulating underground waters, if ascending, may gather oil from places of its origin, and transport it and store it in remote underground reservoirs. On the other hand, oil differs from water in capacity for permeation and osmosis. Oil stored in a tightly sealed bottle will pass by osmosis through the glass more rapidly than water. The question of the underground migration of oil is one of the profound fields for future research.

The principal deductions from the world's experience concerning the occurrences of oil are:

- (1) The chemical origin of oil is as yet unexplained.
- (2) Oil may occur in stratified rocks of any age from the oldest Paleozoic (as in Pennsylvania) to the latest Tertiary (as in Texas).
- (3) Oil usually occurs in terrigenous (land-derived) marine deposits, such as sands and clays, in which there is a mixture of organic matter, and is not common in rocks of deeper

sea origin, such as many of the foraminiferal limestones, or igneous rocks.

(4) The circulation of oil in rocks is different from that of water.

(5) The structure or arrangement of the rocks influences the collection and storage of oil, and hence the knowledge of geological structure aids in the determination of favorable or unfavorable conditions for the underground storage of oil.

(6) Some underground bodies of oil are known to be stored in, or even to be derived from, definite strata. The trained geologist can indicate the underground extent ("embed") of such strata.

(7) Other underground oils are stored in favorable *loci* more or less remote from the strata in which they originated, and accumulated in folds or pockets, like water in a rubber blanket (the blanket being inverted).

The above facts indicate what the geologist can and cannot tell concerning oil-fields. The first thing he can do in the great region is to eliminate or cancel broad areas of unfavorable strata, leaving certain fields of probability and improbability. Within a determined field of probability it is impossible to predict the actual point where oil can be found. The cost and credit of developing the oil-field must always ultimately fall upon those who boldly risk labor and money upon what is largely a game of chance.

The practical geologist has to deal primarily with the stratigraphic location of oil, the deformations of strata favoring the collection of this oil in geological receptacles, and the laws of underground circulation of oil in the rocks.

Where a determined oil-field is underlaid by sheet-oil, the probabilities of success are greater, and the geologist can assist the practical man with some confidence. On the other hand, where the oil-field consists of pockets, no one knows as yet how to locate these pockets beneath the surface.

The oil-bearing strata of the Beaumont oils are entirely different from those of the Corsicana oil-field (where the oils are derived from the Upper Cretaceous strata); from the

Indian Territory oil-fields (where the oils are derived from the Carboniferous strata); and from the oil-fields of Pennsylvania, Ohio and West Virginia (which receive their oil from the still older Paleozoic rocks, such as the Trenton).

The prospector in the Beaumont oil-field must be prepared to cast aside previous conceptions based upon the structure and age of the earlier-known oil-fields.

GEOGRAPHY OF THE TEXAS REGION.

In a recent paper* the author presented an outline of the physiographic features of the Texas region, as shown on a map therewith, and defined its earliest primary natural subdivisions as a basis for more detailed discussion and differentiation of the various phenomena.

The Greater Texas region includes practically all the country east of the Rio Grande and south of the northern boundary of New Mexico. The area thus defined consists of a peculiar group of physiographic units, composed of mountains and plains belonging to the four greater natural provinces of the United States, to wit: the Cordilleran region, the Great Plain region, the Appalachian region, and the Atlantic Coastal Plain. The characteristic features of these regions as they extend into the State present local modifications. There are also in the central portion extensive stretches of country which have no counterpart elsewhere.

It is impossible to give here the details of the varied geographical features of this vast area, which includes nearly one-tenth (Texas proper embracing one-twelfth) of the present area of the United States. In another paper† I showed the rapid evolution which the economic features of Texas have undergone in the past twenty years from the pastoral to the industrial conditions, and declared that the one great need of the State was an economic fuel. Almost coincident with the publication of that paper was the completion of the great oil-wells at Beaumont.

* "Physical Atlas of the Texas Region, U. S. Geological Survey," 1901.

† See *Forum*, August, 1901, and *Encyclopædia Britannica*, London *Times-Supplement*, 1902.

The adjacent ascertained oil-yielding territory of the State, with its probable extension into adjacent States, is indicated on accompanying sketch-map, *Fig. 1*.

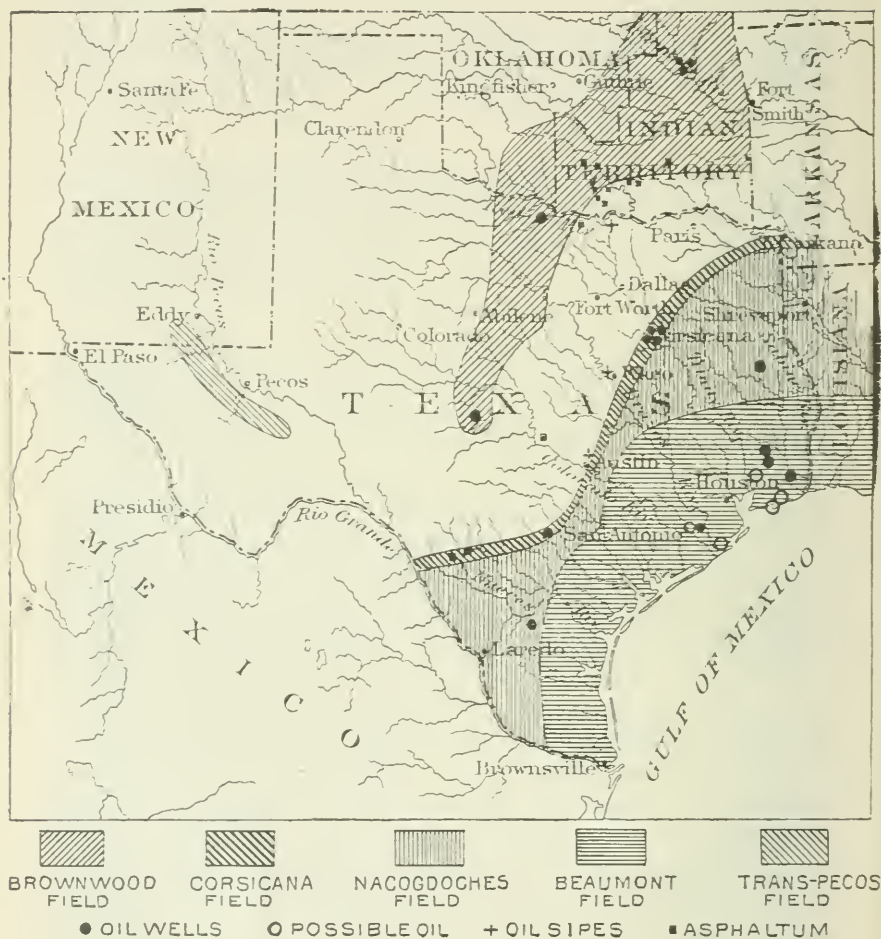


FIG. 1—Map of the Texas oil region and adjacent oil-bearing territory.

SEDIMENTARY ROCKS OF THE TEXAS REGION CONNECTED WITH THE OIL-PROBLEM.

Most of the surface of Texas is formed of sedimentary rocks, igneous formations covering less area. There are

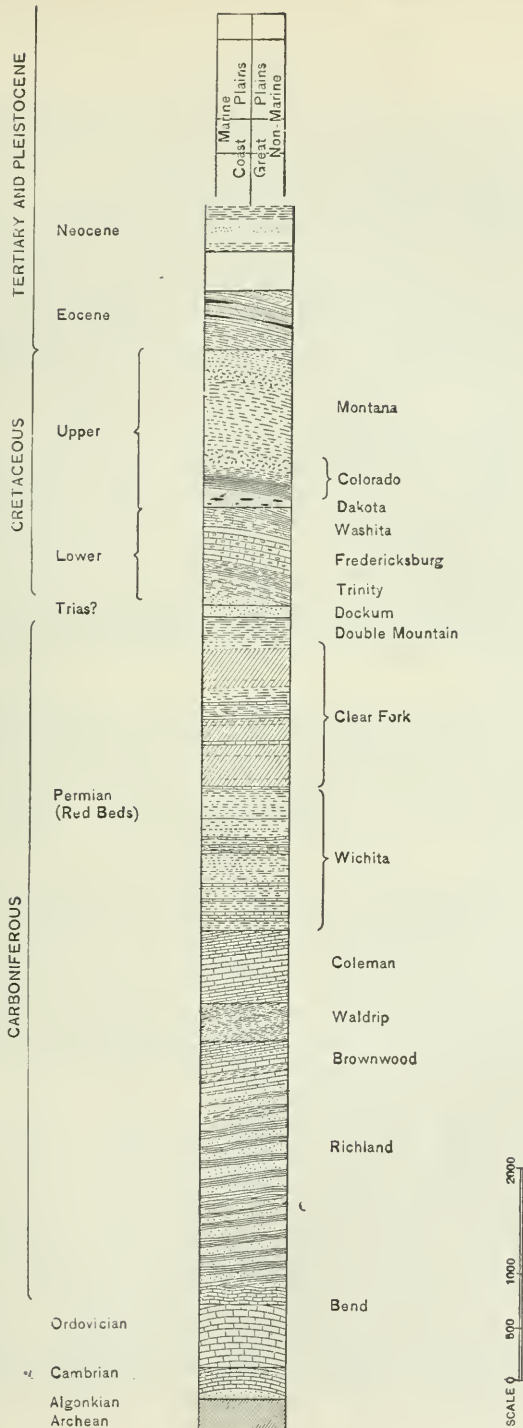


Fig. 2 Section showing the geology of the Texas region.

also extensive formations composed of wind-blown *débris*, chemical precipitates, and upland drift.

The sedimentary rocks are alone pertinent to the present paper. They lie one above another in more or less orderly succession, and are of two general classes: (1) marine formations, originally laid down upon the marginal bottoms of the sea; (2) superficial formations, deposited upon the slopes of the land or at local deposition-levels, such as lakes, rivers or other bodies of water within the land-area.

The marine sedimentary rocks laid down on the sea-bottoms are of all ages, from Cambrian to Recent, with the possible exception of the Devonian. They aggregate about 25,000 feet in thickness, as shown in the vertical section, *Fig. 2*. The strata vary in hardness; are tilted steeply in the mountainous areas, and nearly horizontal on the plains. They are of two general classes, differing in occurrence and importance:

(1) An older or fundamental series of Paleozoic formations. The structural arrangement of these formations in anticlines and synclines is discordant with that of the later formations of the Coastward Slope. The series represent the remains of an ancient topography, which was base-leveled during Jurassic and Cretaceous time, prior to the invasion of the Cretaceous seas, which completely buried it with later sediments. These older rocks, except in the mountains, are now seen only where areas of the later strata have been worn away. In the structure of this group is written an interesting pre-Cretaceous history, involving the growth and decay of relief-features quite different in detail from those of the present time.

(2) Formations of the Coastward Slope from Cretaceous to Recent Age. Most of these rocks were once marginal deposits of the Gulf of Mexico, laid down when it extended much further inland than it does to-day; and they were elevated as the gulf receded from the Rocky Mountain front to its present position. All these strata now incline toward the sea. In some instances the inclination coincides with the surface-slope, while in others it is slightly greater.

The Paleozoic rocks may be divided into two groups—

the earlier and the later Paleozoic. The first includes the Cambrian and Ordovician; the second, the Carboniferous and Permian, or Permo-Triassic. The same names characterize four primary lithologic subdivisions. Of these, the first two are usually more or less associated in geographic occurrence in limited areas, and by reason of their hardness produce allied features of topographic relief. The third and fourth, forming the surfaces of large areas, have each individual features.

The pre-Cambrian and older Paleozoic rocks are the foundations upon which all the other rocks were laid down, and are still, in the main, covered by them. Their outcrops are exceptional and restricted in area; they occur in small districts in the Wichita Range of the Ouchita Mountain system, in some of the trans-Pecos Mountains, especially between the 31st and 32d parallels, and in a limited territory in the southern end of the Central Province, known as the Burnet country.

The Cambro-Silurian rocks are indurated clays, sandstones and limestones. They usually occur in geographic association with the pre-Cambrian and Carboniferous rocks, in the southern part of the Indian Territory and Central Texas.

The Carboniferous rocks are the chief formations of the Ouachita Mountains, the eastern border of the Central Province in Indian Territory and Texas, and certain mountains of trans-Pecos, Texas. The Permian, or Red Beds, prevail in the greater part of the Central Province and in the Pecos and Canadian valleys. The Carboniferous and Permian rocks produce somewhat allied but different topographic forms. The Carboniferous (east of the Pecos), largely made up of soft, impure shales, alternating with harder, coarse brown sandstones and conglomerates, produce ridge-like mountains and a broken belt of country along the eastern margin of the Central Province, called "flats." The Permian Red Beds, some 7,000 feet in thickness, consist largely of unindurated arenaceous clays, with only a few hard strata. They weather into extensive flat regions with occasional scarp-lines attended by "bad-land"

slopes. They occupy the western and greater part of the Central Province, extend beneath the Plateau of the Plains, and outcrop in Pecos Valley against the eastern front of the Cordilleras.

The existence of the early Mesozoic (Triassic) is doubtful, although possible. Rocks referred to this period overlie the Permian along the western part of the Central Province, and appear in small areas around the border of the Plateau of the Plains, but are not pertinent to our present subject. Jurassic limestone strata of the Mexican type have been found in only a limited area in the basin-ranges of the interior desert, west of the Cordilleran front, and are not known on the Atlantic Slope or in the series of the Texas Coastal Plain.

The Coastward Gulf Slope consists of vast sheets of sea-made sediments, from Cretaceous to Pleistocene Age, inclusive, and of aggradational deposits of upland wash, and stream and lacustral alluvium of Tertiary and later age, all of which, except the lower Cretaceous, are mostly unconsolidated terranes of clay, sand, marl, and loam. Of this later group, the marine Cretaceous, Tertiary and Pleistocene rocks are the chief formations, especially east and south of the Central Province. These rocks occur in belts subparallel to the coast.

The Cretaceous rocks are divisible into older or lower and a newer or upper series. They occur along the western border of the Coastward Slope Plain. The older formations consist of hard limestones alternating with clays, and are underlaid by sands; they produce dip plains, cut plains, and low scarps. The Upper Cretaceous strata consist largely of unindurated clay marls, with a few indurated scarp-making strata all underlaid by sands, and weathering into low, undulating areas.

These Cretaceous strata, underlying the Coastal Plain of Texas, in the Black and Grand Prairie countries, have been minutely described by the writer in many papers, especially Part VII of the Twenty-first Annual Report of the Director of the United States Geological Survey. These consist of nearly 4,000 feet of shales and sands and limestones; prob-

ably one-half of the section is made up of marine near-shore clays and sands, and the remainder of deeper water limestones. The Cretaceous strata constitute the floor or foundation upon which the Tertiary and Pleistocene sediments were deposited, and most probably underlie the whole Coastal Plain of Texas at great depth, their base being not less than 10,000 feet deep along the coast at Galveston.

For present purposes the Tertiary may be divided into two great groups, a lower and an upper, which may be termed the Eocene and Neocene, respectively.

The Eocene strata consist of a series of unconsolidated sands and clays, accompanied by fossil shells and beds of lignite, and about 3,000 feet, more or less, in thickness. They have been considerably studied in a manner to make known their stratigraphy and character; but the nomenclature and classification are still susceptible of refinement. The writer prefers for the present to divide the rocks of the epoch into two series. For the older, including all the rocks from the base to the Nacogdoches oil-formation, he has already used the name Camden series. For the rocks above the horizon, the term Angelina may be used. While paleontologists are disagreed in their determinations, these names are good for tentative use.

The Camden series include many beds of clays, sand and lignite (underlying the East Texas timber-belt), for which various names have been proposed.*

The Angelina series, above the so-called marine beds of the Camden series, which are the first classified deposits immediately north of the Beaumont oil-field, have been described by Kennedy, in descending order, as follows:

(1) The Lufkin deposits (Yegua), made up chiefly of dark-blue gypseous clays, and gray sands containing quantities of saline matter. These beds also contain lignite, in many places, in beds or deposits of considerable extent.

(2) The Fayette sands, made up of soft sandstones, light-colored clays, sandy clays, and sands with occasional remains of vegetable life. These deposits approach in texture and

* See various reports of the Texas State Geological Survey.

mode of occurrence the typical Grand Gulf formations, as described by Hilgard, in Mississippi, and by Hopkins, in Louisiana. The plant-remains, such as palms, etc., are also in close correspondence.

(3) The Fleming beds (Frio clays) consist of heavy deposits of clays of various colors, some of them containing concretions of lime and gray sands. The plant-remains of these sands are chiefly wood, and often occur in large pieces and considerable quantities. The Frio clays are considered Eocene in Kennedy's later publications.

The sections made by Kennedy give the general character and sequence of the formations along a general section from Nacogdoches County to the Gulf.*

The thickness of the later Eocene (Angelina series) sections, as given by Kennedy, aggregates 1,407 feet.

Above the Frio clays of supposed Eocene Age follows a series of unconsolidated sands and clays of Neocene, Pleistocene and Recent Ages, which constitute the formation of the Coast Prairie. These will be further discussed on a succeeding page, under the head of the X beds.

Summarized, the post-Carboniferous strata beneath the Central Plain of Texas, and which by dip should be beneath the Coast Prairie, are as follows:

	Feet.
Post-Eocene	1,000 to 2,500
Eocene	3,500
Upper Cretaceous	2,000
Lower Cretaceous	2,000
Total	10,000

STRUCTURE OF THE RUDIMENTARY ROCK-SHEETS.

In general, the Paleozoic rocks of the northern border of the Ouachita Mountains of Indian Territory and the mountains of trans-Pecos, Texas, are greatly tilted as a result of the Appalachian revolution. Between the mountains the Paleozoic rocks in Texas occupy a great synclinal basin,

* Third Annual Rep. Geol. Surv. Texas, 1891, "A Section from Terrell, Kaufman County, to Sabine Pass on the Gulf of Mexico," by Wm. Kennedy, pp. 57, 58, 61, 62, 63.

dipping westward from their exposed eastern outcrops and eastward from their exposed western outcrops.

Over this synclinal basin, after a long land-period, the rocks of the Coastal Plain, from the base of the Cretaceous upward, were laid down unconformably. This unconformity is the most radical structural feature in the whole Texas sequence. It is not necessary for our present purpose to go further into the details of the structure of the Paleozoic rocks.

As a whole, these Cretaceous and Tertiary rock-sheets of the Texas Coastal Plain may be collectively discussed as the systems of the coastward incline, and their structure is very simple, the strata being characterized by their unconsolidated nature, their regularity of sequence, simplicity of arrangement, and gentle dip coastward.

One who begins at the coast and travels across this region along any line radial to the coast, will find that while the surface constantly ascends above the level of the sea at a slight gradient, it presents a descending geologic sequence in successive belts of country, each with its peculiar soil, rock and flora, due to the differences in the rock-sheets of which it is formed. The outcrops of the various strata, owing to their physical and chemical composition, have weathered into diverse characters of country—forest and prairie, broken or level—exactly as the substructure permits.

There are few, if any, breaks in the continuity of deposition of the 10,000 feet of sediments, of Cretaceous and later age, constituting the coastward outline. One of these apparently occurred at the middle of the Cretaceous, but without any special stratigraphic discordance. Another is supposed to have taken place at the close of the Cretaceous, but is not proved.

According to Kennedy, at the close of the period occupied by the deposition of the last of the marine beds of the Eocene, a break of considerable extent occurred; and extensive erosion, implying elevation, appears to have taken place prior to the deposition of the succeeding deposits. Strong proof of this erosion can be seen almost anywhere along the

line of contact where the succeeding denudation has carried off the overlying mantle of sand and gravel of the Angelina series. He says that this want of conformity is everywhere visible, and the clays and sands of the Grand Gulf frequently extend in long narrow strips for several miles into the region occupied by the Eocene marine formations; and at other places are found abutting bold headlands made up of the deposits of that age. Kennedy also informs the writer that there is a similar break at the top of the Angelina series.

So far as known, there are no strong folds or basins in the strata of the Coastal Plain, such as exist in the Ohio and Pennsylvania oil-fields, although there are probably some very low anticlines or swells, which materially bear upon the storage of the oil in the reservoirs or oil-containing strata. In general, the structure of the Coastal Plain is monotonously monoclinal.

The formations of the Coastal Plain are all marginal sediments of the Gulf of Mexico; and the present tilt coastward may be considered the algebraic sum of several periods of elevation and subsidence since the beginning of Cretaceous time, the net result of which is a sinking of over 10,000 feet at the present coast-line.

It is well known that in the epochs from the Pliocene to the present there have been several movements of elevation and subsidence, during which the shore-line of the Gulf of Mexico migrated back and forth. At times this shore-line was far inward from its present site, while at other times it may have been considerably seaward.

It is also probable that the stress resulting from the vertical movements of these strata caused faults, some of which are already known to have taken place along the western margin of the Coastal Plain.

[*To be continued.*]

Notes and Comments.

MANUFACTURE OF SULPHURIC ACID BY CONTACT PROCESS.

In the *Berichte der Deutschen Chemischen Gesellschaft*, xxxiv, pp. 4069 to 4115, was a paper by R. Knietsch on this subject, which will be of importance to all chemists who are interested in it. The great development that the catalytic manufacture of sulphuric acid has already attained in Europe is manifested by the fact that the Badische Anilin und Soda Fabrik alone produced 116,000 metric tons in 1900, against 89,600 in 1899 and only 39,000 in 1894. In the United States the process has already been undertaken by various acid makers, but so great progress has not yet been attained as in Europe. The theory of the process and the various methods of its application were described in *The Mineral Industry* for 1898 and subsequent volumes.

Phillips' application to the formation of sulphuric anhydride of the catalytic action of platinum, which was first observed by Sir Humphry Davy, 1817, dates back to 1831. Not much progress was made, however, until very recently, and the development of the present commercially successful methods was due to theoretical considerations, rather than to any practical results previously obtained. Experiments made with pure sulphurous anhydride and air showed that the practically complete conversion of SO_2 to SO_3 occurred, which proved also to be the case with the gas obtained by burning pyrite; but although the conditions of the laboratory experiments were exactly duplicated, it was found that the activity of the contact substance gradually diminished to zero. Investigation showed that certain impurities in the gas, especially arsenic, exerted a deleterious action on the platinum, very small quantities being sufficient to destroy completely the catalytic activity of the metal. The purification of the gas proved to be one of the most difficult problems in the development of the process; it can be effected only by intimate and thorough agitation of the gas with water or sulphuric acid, which must be continued until optical as well as chemical purity is reached.

The proper regulation of the temperature was found to be another essential feature. Inasmuch as the oxidation of sulphurous anhydride to sulphuric is exothermic, evolving 22,600 calories; and furthermore, since sulphuric anhydride is dissociated at a temperature between 900° and $1,000^\circ \text{C.}$, it was seen that once the reaction was started extraneous cooling instead of heating was necessary. At a temperature below 200°C. , however, there is no reaction. The maximum effect is manifested at about 450°C. It is important, therefore, for rapidity, to use a contact substance possessing its greatest activity at about 450°C. According to Herr Knietsch, the only known contact substance which fulfils that condition is platinum.

The packing of the asbestos is a matter of great importance; it must not be so loose that the gases can pass through without contact, nor so dense as to cause an improper resistance to the passage of the gases. The asbestos is best packed in layers on perforated plates, strung on an iron rod, kept apart by projections; in this way all the tubes of the apparatus can be similarly and evenly packed.

The best absorption medium for the SO_3 gas has been found to be acid containing 97 to 98 per cent. H_2SO_4 ; this is better than either water or acid of any other strength. A single absorption vessel is sufficient for even a very rapid stream of gas, if the strength of the absorbing medium be kept constant by the regular inflow of water and outflow of the sulphuric acid that is formed.

ELECTRIC FURNACE PRODUCTS AND THEIR POSSIBLE USES.

A symposium on electro-chemistry and electro-metallurgy was recently held by the American Institute of Electrical Engineers. C. B. Jacobs discussed some of the remarkable products of the electric furnace, of which calcium carbide is the best known. He suggests that calcium carbide may attain greater importance as a reagent in manufacturing chemistry than in the production of acetylene. It is a powerful dehydrating agent and may come into extensive use for extracting moisture.

The silicides of calcium, barium and strontium are formed in the electric furnace at somewhat higher temperatures than those required to produce the carbides. The silicides decompose with water and yield free hydrogen in a pure state.

It was said in the course of this discussion that these silicides promise to become important in the steel industries through their actions on sulphur and phosphorus. It is stated that by use of these silicides sulphides and phosphides are formed which are eliminated in the slag, and that an iron high in sulphur and phosphorus yielded by this treatment a steel from which the last traces of sulphur and phosphorus were removed.

GROWTH OF THE JAPANESE MERCHANT MARINE.

Food for thought is furnished by some figures which have recently been issued concerning the Japanese mercantile marine. It appears from a statistical statement published by the Japanese Minister of Communications that during the four years ending with 1901 the number of steamships in the Japanese merchant service had increased from 627 to 942, the number of sailing ships from 174 to 3,416, the tonnage of steamships from 429,774 to 557,166 and the tonnage of sailing ships from 24,014 to 315,576. In connection with these figures lies the fact that in 1896 Japan possessed only one merchant steamship of a tonnage exceeding 5,000 tons, but now that country possesses twenty-one steamers whose individual tonnage is above 5,000. The progress which has been made in the extension of its navigation interests by this country, which but recently won a place among civilized nations, is most surprising. At the same time it is a lesson worthy of study by a nation like the United States, so long in the forefront of enlightened nations of the world. We discuss ways and means for increasing our merchant marine service, and while we discuss, the people of Japan push forward. This enterprising Asiatic nation has made great strides in securing a stronghold on the transportation interests of the Pacific Ocean. Japanese vessels are among the largest and best equipped in the Pacific service. Unless the people of the United States take more interest in this matter and adopt practical measures to secure and retain a hold on the commerce of the Pacific Ocean, Japanese steamers will in time control the greater part of that business.—*Iron Age*.

Book Notices.

Text-Book of Physiological and Pathological Chemistry. By G. Bunge. Second English edition, translated from the German edition by Florence A. Sterling and edited by Ernest H. Sterling, M.D., F.R.S., etc. Philadelphia: P. Blakiston's Son & Co., 1902. (Price, \$3.)

The high reputation of the author of this work as the leading exponent of the modern school of bio-chemistry has made his lectures familiar to all investigators in the field of physiological chemistry.

The present English edition from the latest German one brings the subject down to the most recent date, by permitting the incorporation therein of the results of the latest investigations.

The keynote of the work is struck in the third chapter, on the "Conservation of Energy," from the proper understanding of which the modern study of physiological chemistry must proceed.

The work of Bunge is of the highest order of excellence, and it should have a place in the library of every physician who desires to keep in touch with the cope of scientific investigations, while to the student and investigator it should be wellnigh indispensable. The value of the work to the latter is greatly enhanced by the elaborate system of references to original sources adopted by the author. W.

Alternating Current Machines: Being the second volume of "Dynamo-Electric Machinery;" its construction, design and operation. By Samuel Sheldon, A.M., Ph.D., and Hobart Mason, B.S., E.E. New York: D. Van Nostrand Company; London: Crosby Lockwood & Sons, 1902. (Price, \$2.50.)

This work is a companion volume to the work on direct-current machines by the same authors, and like that, is intended as a text-book in technical schools. It treats of the properties of alternating currents; self-induction; capacity; problems in alternating current circuits; alternators; motors; converters; power transmission and tests.

The various types of alternating-current machines described and illustrated are those of American makers. W.

Standard Polyphase Apparatus and Systems. By Maurice A. Oudin, M.S., etc. Third edition revised. 8vo. pp. 289. New York: D. Van Nostrand Company. London: Sampson, Low, Marston & Co., 1902. (Price, \$3.)

After defining alternating-current terms, the author treats of generators, induction motors, synchronous motors, rotary converters, static transformers, station equipment and general apparatus; the two-phase, three-phase and monocyclic systems; choice of frequency, the relative weights of copper for various systems, calculation of transmission lines. An appendix treats of the standardization of generators, motors and transformers.

The revision of the third edition appears to have been thoroughly done, bringing the work up to date. The printing and illustration of the work are notably good. W.

Electrical and Magnetic Calculations for the use of electrical engineers and artisans, teachers, students and all others interested in the theory and application of electricity and magnetism. By A. A. Atkinson, M.S. New York: D. Van Nostrand Company, 1902. (Price, \$1.50.)

The following subjects are considered: Units and their explanation; relation of quantities; general laws of resistance; electrical energy; alternating currents; wiring for light and power; batteries; magnetism, relation of magnetic quantities; the E.M.F. of dynamos and motors; calculation of fields; elements of dynamo design.

Examples with solutions are given under each subject. The illustrations are numerous and excellent. W.

The Arithmetic of Electrical Measurements with numerous examples, fully worked. By W. R. P Hobbs, R.N. Revised to date by Dr. Richard Wormell, M.A. Ninth edition, small 8vo, pp. 112. London: Thos. Murby; New York: D. Van Nostrand Company, 1902. (Price, 50 cents.)

The arrangement of this booklet is such as should commend it specially to students and those practically engaged in the electrical arts. The fact that it has gone through nine editions would seem to demonstrate its utility.

The work of the present edition has been bestowed principally in the replacing of a number of obsolete or obsolescent terms by their modern equivalents, and the introduction of some explanatory matter, definitions, etc. W.

Historie de l'Observatoire de Paris de sa Fondation à 1793. Par C. Wolf, membre de l'Institut, Astronome honoraire de l'Observatoire. Un volume grand in-8 de xii-392 pages, avec 16 planches. Paris: Gauthier-Villars, 1902. (Price, 15 fr.)

This embraces a history of the matériel and personnel of this famous institution, based upon authentic documents. It is illustrated by an interesting frontispiece and fifteen well-executed plates of plans and elevations of various portions of the buildings. W.

Quelques Reflexions sur le Mécanique suivies d'une première leçon de dynamique. Par Émile Picard, membre de l'Institut. Paris: Gauthier-Villars, 1902. (8vo, pp. 56).

This work is a publication in separate form of a chapter on the principles of mechanics from an official scientific report made by the author on the Universal Exposition of 1900. The chapter is concluded by a primary lesson on kinetics reproduced from the author's lecture-course at the École Centrale des Arts et Manufactures. W.

Die Beobachtungsfehler und die Methode der Kleinsten Quadrate mit ihrer Anwendung auf die Geodäsie und die Wassermessungen. Von Otto Koll, Professor, Geh. Finanzrath im Könl. Preuss. Finanzministerium. (Mit in den Text gedruckten Figuren.) Zweite Auflage. Berlin: Julius Springer, 1901.

This work, which is presented in a second edition, treats of the "Errors of Observation" and their various sources, limitations, etc., and of the application of the "Method of Least Squares." W.

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Agriculture in Its Relations to Bacteria and Other Ferments.

BY H. W. WILEY,*

Chief of the Bureau of Chemistry, U. S. Department of Agriculture—
Honorary Member of the Franklin Institute.

(*Concluded from p. 90.*)

Alinite has been subjected to extensive experiments by foreign chemists. For the practical use of the material it is mixed with water, and the infusion is applied to the seeds before they are sown. From 500 to 1,000 individual organisms are said to adhere to each seed. Many experiments with alinite have been made but the practical value of the substance is a question which must be left open for future experimental study. Theoretical considerations point to two conclusions: First, it seems logical to expect that if we plant with the seed large numbers of organisms, capable of rendering available the humus nitrogen already contained

*A lecture delivered before the Franklin Institute, Friday evening, November 1, 1901.

in the soil and endowed with the power of absorbing more nitrogen from the air, the young plants should begin their growth with a vigor and rapidity which would insure an abundant harvest. On the other hand, it must not be forgotten that bacteria in a favorable environment multiply with wonderful rapidity. Therefore, it seems that the good effects of this species of ferment would be more largely secured by establishing conditions favorable to their growth than by attempting to inoculate the soil with large numbers of them originally. In the present condition of our knowledge, therefore, it must be considered that alinite is of much more doubtful utility than nitrogen, and in both instances the future offers a problem of wonderful interest in connection with their study and development.

POSSIBLE SOURCES OF FUTURE NITROGEN.

From the above outline, it appears that the nitrogen on which the farmer of the future is to rely will be derived from various sources.

(1) The immense stores of nitrogen already existing, which Nature has stored up in ages past for the use of man, will continue to be one of the chief sources of supply for an indefinite time. These nitrates are found in caves and other protected places and in regions where the rainfall has not been sufficient to dissolve the products of nitrification as they have been formed. Vast areas are found in South America in which the soil is more or less saturated with these stored nitrates, among which nitrate of soda or Chile saltpeter is the most important.

(2) There will be those nitrogenous materials saved in fertilizers and applied directly to the fields.

(3) There will be the inorganic nitrogen which becomes fixed by electrical discharges and other chemical processes, and especially through the activity of certain micro-organisms living in symbiosis with leguminous plants.

(4) A possible source not yet determined, due to the activity of organisms not symbiotic, but capable of fixing nitrogen in a form fit for plant-food directly or through some intermediary not yet well known.

The advances in our knowledge of nitrification, and the organisms producing it, have developed new sources of scientific activity relating to agriculture. A study of the soils at the present time is incomplete without a thorough investigation of the character of the nitrogen which they contain and the nature and number of the nitrifying organisms active therein. Thus a new branch of agricultural research has been established.

For several years the Bureau of Chemistry of the Department of Agriculture has pursued studies of this description. From all parts of the country samples of soils have been secured, not merely for physical and chemical examination, but also for the purpose of studying the nature of the nitrifying organisms. To this end a new method of procedure had to be invented and tested. The problem of securing samples free from contamination with other organisms was one of considerable difficulty. This problem we have endeavored to solve in the manner described below.

Sterilized sampling tubes are prepared and covered with rubber caps as illustrated in the appended diagram. The tube is made of brass beveled at one end so as to easily enter the soil. The tube, rubber caps and the rubber balls, which are placed in them to prevent the cutting action of the edges of the tube, are subjected to a sterilizing temperature for an hour or two on three successive days. Any spores which may have escaped destruction in the first sterilization are permitted to develop and are destroyed in the successive sterilizations. The blunt end of the tube is filled with a plug of sterilized cotton, which serves to permit the egress of the air when the sharp end of the tube is forced into the soil to secure the sample.

In securing a sample, a ditch is dug of sufficient magnitude to easily hold the operator and to a depth of 3 or 4 feet. One side of this ditch is made as smooth as possible, and the points at which the samples are to be secured, beginning usually at 3 inches below the surface and continuing at stated intervals to the bottom, are marked. A platinum spatula, sterilized in the flame of an alcohol lamp, is used to remove the surface at the point where the sample

is to be obtained. Both rubber caps are then removed and the brass tube is forced with a turning movement into the soil so as to fill the interior with a core of the earth. The tube is withdrawn, the rubber caps restored and the whole enclosed in a mailing sack, which is then transmitted to the chemical laboratory for future examination.

The principal pieces of apparatus employed in this operation are shown in *Fig. 13*.

The samples, when they reach the laboratory, are used for seeding sterilized solutions containing nitrifiable nitrogen under standard conditions. The amount of nitrous and nitric acids produced by the seeding with different soils is measured from time to time and thus the comparative nitrifying power of the sample is determined. The respective quantities of nitrous and nitric acids are best shown in a graphic way as illustrated by the appended diagrams.

The figures in the vertical column show the parts per million of total nitrous and nitric acids produced.

The continuous black line indicates the total nitrification due to the sum of nitrous and nitric acids.

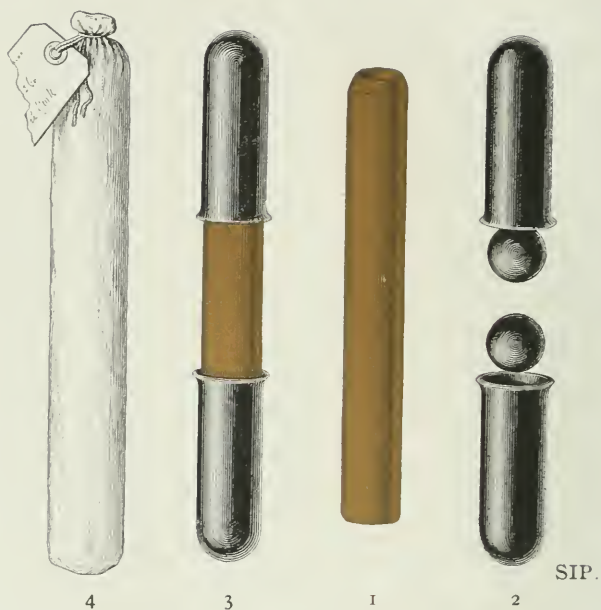
The dotted line shows the quantity of nitrous acid at any given moment.

The difference between the dotted line and continuous line at any point shows the excess of nitric acid over nitrous acid at any moment.

It is evident that the nitrous acid is first formed; after a short time the nitric acid begins to show itself, and at the end of the experiment the nitrous acid has practically all disappeared and the total acidity present is due to nitric acid.

It is evident that all studies of this kind in the beginning must be, to a certain extent, crude and imperfect, but they mark the path along which progress will be made and show a new departure in the study of soils, which should enable the agricultural chemist of the future to determine by experimental methods the power of a soil for nitrifying purposes.

In the study of the nitrifying organisms, as outlined in the foregoing address, I have had the valuable collaboration of my assistant, Mr. E. E. Ewell. With rare skill and



Sterilized tube for securing samples for nitrificative studies.

No. 1.—Brass tube.

No. 2.—Rubber caps and balls.

No. 3.—Tube sterilized and coppered.

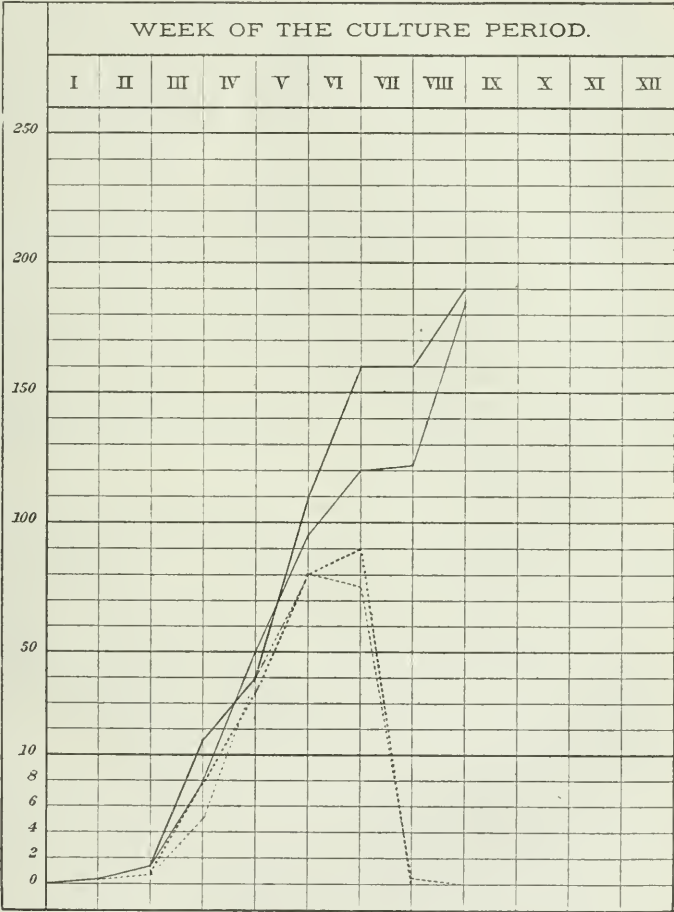
No. 4.—Tube ready for shipment by mail.

RECORD OF THE PROGRESS OF NITRIFICATION IN CULTURES Nos. 301 and 301a

Sample No. 1.
Source of the sample, College Station, Texas
Kind of soil, virgin.
Date of taking the sample, April 20, 1895.

Serial No. 14186.
Depth below surface, 3 inches.
Vegetation growing thereon, native grasses
Date of sending cultures, May 3, 1895.

CHART SHOWING PROGRESS OF NITRIFICATION IN DUPLICATE IN CULTURE MEDIA
SEEDED WITH SOIL FROM COLLEGE STATION, TEXAS.
Nitrogen changed from the ammoniacal form to the nitrous and nitric forms—parts per million of the culture fluid.
Nitrous nitrogen { . . . 301 } ; nitrous nitrogen plus nitric nitrogen { . . . 301a } .



patience and great industry he has worked out the details of the problems connected with the experimental work, and by his valuable and timely suggestions improved the methods and processes which were at first prescribed.

The foundations of a new research which have just been laid we hope may serve as a superstructure for future inves-

tigations which will develop and establish the very best possible methods for the study of soil ferments.

THE PROBLEM OF EXHAUSTED SOILS.

One of the most practical problems in regard to nitrification is that which is presented by exhausted soils. Soils may become unfertile through the direct exhaustion of their nitrogen content by successive croppings, by leaching, or by reason of the environments being unfavorable to the growth of nitrifying organisms.

By reason of the fact that American agriculture has been conducted for so long upon the plan of highway robbery, we are confronted in this country with vast areas of exhausted soils, whose unfertility is principally due to lack of humus and of nitrogen, particularly in the form of nitrates. Experience has shown that it is useless to try to restore such soils by the growth of leguminous plants, and, where the nitrifying organisms are deficient, by the addition of organic nitrogenous matter.

Leguminous plants grow only on fertile soils and can be used to maintain and increase, but not to create, fertility. With such soils the best recourse is to nitrogen already available; that is, some form of nitric acid. The cheapest source at present is sodium nitrate, or Chile saltpeter.

Fortunately, Nature has made abundant provision of these stores, so that the scientific farmer has at hand a means whereby soil fertility can be created.

While the knowledge of the principles of nitrification is only recent, Nature has waited upon Science, but from the earliest times has conducted this nitrifying process literally in the dark. Long before the advent of man upon the earth the nitrifying organism was abundant and vigorous and was plying its vocation without man's knowledge.

Wherever other conditions of nitrification existed, and the rainfall was deficient, the products of nitrification have accumulated, sometimes in enormous quantities, so as to form regular strata of nitrates. The most remarkable known case of this is the formation of the extensive beds of sodium nitrate in Chile, and to a limited extent in Egypt.

The nitric acid is combined with calcium in some cases, in others with potassium, and in the most extensive deposits it is combined with sodium to form sodium nitrate, which at present is the most important source of supply. It is thus that over large areas of arid and semi-arid regions, and in caves and other protected places, vast stores of nitric acid have accumulated. These beds of accumulated nitrates represent the conserved energy of long periods of intense activity of nitrifying bacteria, living and operating under favorable conditions in the past, and constitute an important source upon which scientific men may draw for developing a system of intensive agriculture at present, just as they draw upon the conserved energy of the sun's rays, stored in our beds of coal, to develop the steam and electricity so indispensable to our commercial and manufacturing enterprises. In both cases it is the utilization of the conserved energies of long periods of activity in the past for meeting the demands of modern life. The sodium nitrate beds constitute a reservoir of potential energy for the development of modern intensive agriculture.

Scientific agriculture has taught the farmer how to draw upon these stores and to make them subservient to his uses. He is thus able to begin with an exhausted soil and produce a luxuriant and profitable growth.

It is well known that the leguminous crops will not grow except in a reasonably fertile soil, and hence it is useless to expect the restoration of fertility to an exhausted soil by a natural means. The use of nitrate of soda, dissolved phosphate and potash in proper proportions, combined with scientific tillage, will cause the most exhausted soil to produce a crop. By plowing in the crops thus produced and adding humus to the soil, in a few years the unfertile field will become largely productive. In this manner, humus and other necessary ingredients are obtained and added to the soil, and the conditions of fertility are provided which will favor the growth and maintenance of leguminous and other crops and thus preserve and even increase the fertility produced.

We must regard, therefore, the natural deposits of nitrates, particularly those of sodium nitrate in Chile, as

one of the most important resources at the hand of the farmer for the rejuvenation of impoverished soils. This, however, is not the only use of natural nitrates; they are especially valuable for intensive culture in gardens and fields tributary to large cities where quickness and abundance of growth are factors of prime necessity. The ready-formed nitrate is an indispensable fertilizer for flowers and gardens as well as for fields. It performs a function which cannot be easily replaced by any other form of nitrogenous material among field crops. It has been demonstrated especially that the sugar-beet is an object to which the sodium nitrate can be directly and profitably applied, affording a more economic form of nitrogenous fertilizer than can be secured in any other way. The beet is only a type of many field crops demanding ready-formed nitrates in addition to the gardens and market-garden farms already described.

It appears, therefore, that advancing knowledge in agricultural chemistry, showing how organic nitrogen can be best assimilated, and in what manner inorganic nitrogen can be fixed and made ready for use by means of symbiotic organisms, only increases the means of carefully conserving and wisely using the natural deposits of nitrates already discovered. Advancing agriculture renders of greater interest the discovery of beds of nitrates yet unknown, whose treasures can be added to the assets of the scientific farmer.

To me, it seems that a wise use of the resources which Nature has placed at our disposal, together with a practical application of the principles of science, will serve to show how a properly managed soil can be increased in fertility instead of exhausted by continuous cropping, thus removing any fear of the fate of starvation.

The fields of the future, instead of becoming poorer will grow richer; the average yield of foods per acre will increase so that the coming increasing millions of the world's people will be better fed, better clothed and better taught than those that have gone before.

It is not the fear of starvation that confronts men in the remote future. If this planet, as is probable, is to live its

day and die as others have done, it will not be because of the exhaustion of the earth's supply of plant-food. The circuit of life is complete, and no item of matter which has once been available for plant-food can ever be hopelessly lost for the same purpose.

In the changes which come and go the vital molecule of matter will again live even it have been dead for thousands of years. Science and practice will add indefinitely to the stores of human food, and the scientific agriculture of the future years will be ready to feed the mouths which come into existence.

For every mouth, it must be remembered, Nature provides two hands. The capacity of the mouth remains constant while the ability of the hands to fabricate, to make and to earn is constantly increasing. The future, therefore, will bring more leisure, more ease, more culture and more food.

Should the races of men ever cease to exist upon the face of the earth, as is possible, it is evident to my mind that a cosmic and not any economic cause will bring about the result.

It seems more probable that the earth is gradually cooling. Paleontology finds evidence of tropical life, both plant and animal, far in the polar regions. It seems that all life is gradually approaching the equator. The armies of ice are slowly but surely advancing their lines, and the time may finally come when the last man will reach the equator. Far in the millions of years will this event take place. Dwarfed in stature, flat of head and hopeless of face will this last man be—the remnant of civilizations and of nations long extinct. Exhausted with his struggle for existence he will calmly and hopelessly await the end.

The future will not see the fulfillment of the prophecy of Berthelot when all men will be fed food formed in the chemist's crucible. The future will not see the fulfillment of the prophecy of Crookes when all men shall starve for the lack of wheat which farmers can no longer grow. Only a future too remote to be finite can possibly see the fulfillment of the prophecy which sees the end of humanity in a universe of ice.

AN IMPROVED FORM OF APPARATUS FOR PRODUCING THIN FILMS BY ELECTRO-DEPOSITION.

Herr Endruweit, of Berlin, has patented an improved form of apparatus for producing thin films by electro-deposition. An endless metal band is first coated with potassium sulphide, and, after washing, is passed through a nickel bath of the usual composition. The thin film of nickel obtained in this way is backed by copper (by passing through a similar bath containing a copper salt in solution) and by tough paper, before being stripped from its support. A strong sheet or roll of paper faced with bright metallic nickel can be obtained in this manner, and the use of this material after relief-stamping and coloring, for wall-papers and for advertisement show-cards is said to offer many advantages. The electro-deposited "paper" is also reported to be useful for packing the stuffing boxes of high-pressure steam engines, and, if sold at reasonable rates, it is possible that there are many uses for which it may prove suitable.—*Scientific American*.

TURQUOISES FROM RUINS.

The exhibits of the American Museum of Natural History will soon be enriched by a fine collection of turquoise objects obtained from the ancient ruins of New Mexico. The collection was brought in a few weeks ago, and contains many objects which are unique and of great scientific value, aside from their intrinsic worth.

Turquoise is essentially the American gem, not only in the sense that it is most highly valued by all the Indian tribes, as it has always been by their ancestors, even long before the days of Columbus, but also because within the past few years the American product has practically driven out of the market the Persian and other imported stones. An examination of the gems offered for sale by one of the leading jewelers on Union Square the other day showed ten American stones to every one that came from other countries, and demonstrated, moreover, that the home-product is superior in every way to the imported, especially in that peculiar blue color, which, like the "pigeon's blood red" of the ruby, gives the gem its value.—*Scient. Am. Suppl.*

MELTING SNOW BY STEAM.

The heavy snowstorms of last winter, which for several days blocked the enormous traffic of New York City, brought to light three curious machines employed by the Street Cleaning Department for the removal of snow. In general appearance these snow-melters resemble a road-roller without rollers. In place of the forward rollers is a large iron box, into which a dozen men shovel snow. Behind the box and extending to the rear end of the machine is a boiler, from which two funnel-shaped pipes about a foot in diameter extend into the box. Steam is forced from these pipes through jets into the box, and the snow melts as fast as it is dumped into the box. The water runs down into a sewer. In eleven hours one machine removed 750 yards of snow. Nine teams were able to do the work for which seventy-five were formerly required.—*Scientific American*.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, February 19, 1902.

President JOHN BIRKINBINE in the chair.

The Metric System of Weights and Measures.

(Concluded from p. 120.)

SOUTHWARK FOUNDRY AND MACHINE COMPANY.

PHILADELPHIA, February 4, 1902.

To the Secretary :

Your favor of the 26th ult. respecting the introduction of the metric system in the United States, and requesting our opinion as to the advisability of same, is received.

We are earnestly opposed to its introduction in our line of business, for we believe the present system of measurement is more convenient, and just as efficient in every way.

The writer was at one time connected with an establishment wherein the metric system was employed in one department and the English system in the rest of the works. It was his experience that foreigners who were used to the metric system, after learning our system, preferred to work with it rather than the metric in making drawings; in other words, preferred to work in the department using our present system, rather than in the department where they used the metric.

The writer spent some time abroad a few years ago, and found that for convenience, they used as few decimals as possible upon their drawings, as it was difficult in many places to find room for the figures, just as we try to avoid fractions containing too many figures for convenient insertion.

In addition to the above reasons, we desire to say that it would put us to a serious expense to change all our standards to comply in a practical way with the metric system; a sacrifice we do not feel, under the circumstances as explained above, we should be called upon to make.

Very truly yours,

SOUTHWARK FOUNDRY AND MACHINE COMPANY,

JAS. C. BROOKS, *President.*

To the Secretary :

The feasibility and advisability of the adoption of the metric system in the United States is not a new subject of discussion in this hall. The older members of the Institute will, no doubt, recall the fact that in 1876 a committee was appointed, to whom was referred a circular of the

Boston Society of Civil Engineers asking the co-operation of the Institute "in petitioning Congress to fix a date after which the metric weights and measures shall be the only legal standards."

Two reports were presented, the majority opposing the measure chiefly, I believe, on the ground of great cost and appalling confusion which would result to manufacturing industries by the substitution of the metric system for the standards in daily use.

The concluding words of the majority report were as follows:

"The Franklin Institute has never placed itself on record as opposing true progress; it has always advocated changes which were beneficial and not destructive. In this case, a majority of your committee believe that the ultimate benefits of the change proposed would be of less value than the damages during the transition. They think that the Government of the United States has already done all that can be fairly asked of it by the most enthusiastic advocates of the metrical system, by making it legal. Those of us who choose to do so can use that system, and no one can object to it; but for the Government to require us to use that, and no other, would be an arbitrary measure which we are neither willing nor able to bear. The majority of your committee are of opinion, and so report, that the objections to the attempt to adopt the *meter* as a standard unit of lineal measure are overwhelming, whether we consider the compulsory means proposed or the end to be attained.

"All of the objections to the metrical system do not apply to the adaptation of the decimal scale to our existing units. In the decimal harmony between the cubic foot and its content of water weighing 1,000 ounces avoirdupois, whereby a cube $\frac{1}{10}$ of a foot on the edge becomes the measure of the ounce of water, we have the means of constructing a decimal system of weights and measures which would interfere the least with existing institutions. But your committee do not feel called upon to consider this branch of the subject."

The minority report, while differing from the majority report in certain particulars, agreed with the conclusions of the majority of the committee, so far as related to the subject specifically referred to them, viz.: that "it is inexpedient to attempt at present to anticipate, by enactment, the time when this great step in the progress of human civilization and unity shall be taken by the National Government of the United States."

In the quarter of a century that has elapsed since this important subject was so ably discussed by the special committee of the Franklin Institute, manufacturing industries in this country have advanced to a marvelous degree, so that, instead of occupying a comparatively unimportant position in the markets of the world, they have forged to the front and have become dominant. This fact is of prime importance in

considering the advisability of the adoption of the metric system in the near future.

The members of the committee recently appointed to consider this subject are abundantly able to estimate the force of the objections raised by the majority of the committee of 1876 to the adoption, at that time, of the metric system, and, furthermore, it should be observed that the proposed resolutions do not contemplate an immediate compulsory substitution of the metric system of weights and measures as the sole standard in the United States, but that "the National Government should enact such laws as will ensure the adoption of the metric system of weights and measures as the sole standard in its various Departments as rapidly as may be consistent with the public service."

In conclusion, I may say that I am in favor of the resolutions.

ALEX. E. OUTERBRIDGE, JR.

PHILADELPHIA, February 12, 1902.

To the Secretary:

* * * The question of the adoption of the metric system by the United States may be regarded as having passed the academic stage, and as a purely practical one under present world conditions. Scientific men everywhere, recognizing the advantages of that system for record and computation, have not only settled the question for themselves, but have caused its incorporation by the more recent advanced applications of science, so that familiarity with it is becoming absolutely necessary to those concerned with such applications. For external commercial purposes on a large scale, it is becoming absolutely necessary for the United States to put it in complete touch with those nations which she most desires to reach in trade, which have generally adopted it. And, on the other hand, adoption by the United States would tend greatly to its early universal adoption. For internal purposes, the multitudinous minor retail transactions, whilst the transition from the present system, or rather want of system, might be attended with some inconvenience, this would be but temporary, and might in fact prove much less than might be anticipated with the American people, whilst the advantages would be permanent.

In reaching this conclusion any advantages of the metric system are not overestimated, nor its disadvantages overlooked. In many ordinary operations the question of record and computation are the least involved, whilst the arbitrary, unnatural, if you please, decimal division may lack convenience and adaptation in many of the minor transactions of the people. But the most practical question involved is not one of a standard and its divisions, but rather of uniformity of standard and its divisions as against a perplexing diversity of standards and divisions, often inexplicable and causing confusion and ambiguity even for experts, a

condition of affairs which all the time and labor and instruction in the schools, according to my experience with many of the best educated in them, can do practically little or nothing to relieve.

In this connection, it would seem that an advantage in the adoption of a radically new system, such as the metric, would be found in its freedom from further possible confusion, which any attempted recasting or adjustment of the present system would inevitably contain with the retention of old names and divisions. As to the names and divisions of the proposed system, they will rapidly adjust themselves to the masses, as those of the present currency have done, with the halves and quarters, and the suggested recoinage of the half-cent to make the eighth possible, whilst for accounts and computations all the advantages of the prevalent arithmetical notation.

Whether the decimal system is the best, whether the inconveniences and absolute losses occasioned by its adoption in some directions would be justifiable, and many questions of a similar character, are met by the unmistakable trend toward its universal adoption, that the United States, in its competition for external trade, would be compelled sooner or later to fall in with ; so that, upon the whole, it cannot but be regarded as the wisest policy to inaugurate the change at the earliest date, and carry it out as rapidly as possible. Yours truly,

CHARLES F. HIMES.

CARLISLE, PA., February 18, 1902.

To the Secretary :

THE ENGLISH *versus* THE METRIC SYSTEM.

While the American Society of Mechanical Engineers is taking steps to prevent legislation by Congress for rendering the use of the metric system compulsory, the Franklin Institute in its meeting on February 19, 1902, has passed resolutions recommending such legislation. It can therefore not be considered as inopportune if at this date some further arguments on the main question thus at issue be presented, and in special such arguments which, although of fundamental importance, have never before been presented.

The claim of superior scientific merit in the metric system rests on the qualities of the system, as here below stated, namely :

(1) The metric system uses, in the division of distances and of matter, a system which is in absolute harmony with the arithmetical system conjointly used therewith. (Under the English system the division-system for distances is the duodecimal system in part, or only imperfectly carried out, and the arithmetical system is the decimal system, and the division of matter is neither duodecimal nor decimal nor is in disharmony with the rest of the English division-system.)

(2) The metric system involves the conditions for immediate conversion of volume into weight and *vice versa*, when density is known; because the weight-unit is that of a known volume-unit of water, the density of which is the unit of all other densities.

(In the English system the necessity exists of using, aside of the density-figures, in such conversion the weight of a volume-unit of water, such as lb. 0.036118 for a cubic inch.)

It does not appear that a change of our arithmetical system is advocated, except by those radical scientists who assert that no arithmetical system is rational, unless it is rooted in the powers of a product of 2 and 3, or of a multiple thereof, for many good and valid reasons, one of which is the discomplication of logarithmic values under such a system.

Therefore, it may be considered as altogether out of all discussion that we change from our decimal arithmetical system to the use of powers of 12, or to the duodecimal system. Then the issue is narrowed down to the problem of adapting the English division-system of distances and of matter to the decimal arithmetical system. If this should be found impracticable, then there is no resisting the full acknowledgment of the absolute superiority of the combined decimal and metrical systems.

It is the purpose of this, my present writing, to claim that such adaptation as mentioned is both possible and practicable.

A careful and critical investigation of all arguments advanced in favor of the English system of measuring distances and volumes reveals the fact that essentially they are arguments in favor of preserving the inch.

Why then should the English or thenceforth the American system of measuring distances and volumes not be improved by adopting the inch throughout as the unit? We may then reduce the new or American foot to 10 inches. We have then 1 rod 200 inches in place of 198, and make it 5 yards, or the yard 40 inches instead of 36 inches. And nothing prevents us even from dropping the terms yard and rod altogether and in speaking in the American system of ten-foot, hundred-foot and mil-foot measures.

While thus harmony be created between division-system and arithmetical system in our own American system—the interconversion between volume and weight, that great virtue of the metric system, still remains unattended to.

It cannot be said that such conversion-possibility be of less importance to the mechanical engineer than to the civil engineer, both professions meeting with the frequent necessity of determining weight by a known volume.

To restore harmony under the American system between the method of interconversion and division, we have to start from the same unit, namely the *inch* or *cubic inch*. In present pounds the cubic inch of water, at its highest density, weighs 0.036118 pound. Assuming 3,611.8

pounds to be made the equivalent of 4,000 new or American pounds, and such to be made the standard bi-ton, the equivalent of a volume of 100,000 cubic inches of water, the American ton would weigh 2,000 pounds new or American weight, or 1,805.9 pounds of old weight, and be the weight of 50,000 cubic inches of water at highest density, or at a temperature of 39° F. Therefore, by the reduction of our present pound to 3611.8,4000 of its weight to become the new American pound, such American pound would have the precise weight of 25 cubic inches of water.

This leads to the conclusion that there should be a new weight unit of an American bi-kilo or the equivalent of 4 American pounds weighing as much as 100 cubic inches of water. A cube of 10 inches or of 1 American foot of water then would weigh 10 bi-kilos.

One of the characteristic and advantageous features of such adaptation of the American system, the same as of the metric system, to intra-conversion of weight and volume deserves special attention, namely the facile handling of all calculations of mechanical resistance and equivalent power in continuous action, such as, for instance, of an impinging water-jet. The general equation reads :

$$H \cdot P = \frac{(F \cdot v) \cdot \frac{v^2}{2g}}{s} \quad \text{or} \quad \frac{F \cdot v^3}{s \cdot 2g}$$

F indicating the transverse section of the impinging jet, on condition that a column of such jet 1 foot long shall weigh 1 pound.

s indicating the foot-pound equivalent per horse-power second, under the prevailing system = 550, but under the proposed American system as $550 \cdot 1.2 \cdot 4.36118 = 731$, the values v and g being used as in general acceptance;

$$g \text{ becoming } = 32.183669 \times 12/10 = 38.62.$$

According to the valuation of the foot and of the pound under the proposed American system, a column of 1 American foot or of 10 inches length weighs 0.4 American pounds if it has a base of 1² inch, hence in order to weigh 1 American pound, its base or its transverse uniform section must be as 1² inch $0.4 = 2.5$ square inches.

Assuming a 54-foot velocity under a 52-foot head and a circular orifice of ejection of 2 inches diameter or of 3.1416 square inches.

$$(a) \text{ By } \frac{3.1416}{2.5} = 1.25664 = F, \text{ and}$$

$$(b) \text{ By } H \cdot P = \frac{1.25664 \cdot 54^3}{731 \cdot 2 \cdot 38.62} = 3.5 H \cdot P.$$

This must of necessity appear as less than calculation with feet of 12 inches in place of 10 inches would show, because the reduction operates at the cube of velocity, by $10^3/12^3 = 0.579$.

And to the meritorious feature, thus demonstrated, of the adaptation rather of our present fundamental unit of measurement—the inch—to the inter-conversion or metric system, in preference to its abolition, I may show a further addition by mentioning that by substituting, instead of F , and expressed in the same units of 2.5 square inches, the value B/d , or properly the value $B/(d \cdot 2.5)$; B being the weight in American (new) pounds of the water displaced by the ship in its immersion—and d being the length of the ship in the direction of its motion on the water-line—the mathematically provable resistance to ship's motion and the power required for such motion may be calculated precisely. The proof of such equation rests on the consideration of the serial positions of ship in repeated lengths of its own (as if in ice), and of the fact that quantities not so indicated as displaced, reoccupy (in quantity, though not in identity) former position, as well as on the actual demonstration that not friction but volume and its form are the conditions for resistance by the medium, subject to the coefficient of density of the medium, which for water is as 1. (Compare this *Journal*, 1893, Nos. 3-5.)

F. M. F. CAZIN.

HOBOKEN, N. J., March 12, 1902.

AMERICAN WALTHAM WATCH COMPANY.

WALTHAM, MASS., February 5, 1902.

To the Secretary:

We are in receipt of your communication of 1st inst., together with the report of your committee, who have had under consideration the merits of the metric system of measures. * * * We desire to say that we agree with the conclusions of your committee in every one of the questions specified. We may say that for more than thirty years we have employed the metric system of linear measurement as being greatly superior in convenience for the minute measurements required in the manufacture of watches. In adopting this system we took a centimeter as our unit of measurement. This we subdivide into a thousand parts, and have special gauges reading to thousandths. In many instances we subdivide by the eye the graduations on our gauges. Having this system in use for measurement of watch parts, we also use it in our machine department in the manufacture of machines, and while it is somewhat novel to men when they first come to us, yet they very readily acquire the system, which is extremely simple in computation.

We trust that the deliberation of your society will in some measure hasten the adoption of this system as a Government standard of measurements.

Yours truly,

AMERICAN WALTHAM WATCH COMPANY.

E. A. MARSH, *Gen'l Supt.*

BAUSCH & LOMB OPTICAL CO.

ROCHESTER, N. Y., February 18, 1902.

To the Secretary :

Replying to your favor of the 15th inst., we wish to express ourselves as heartily in favor of any plan which will hasten the adoption of the metric system in this country. We have used the system in our workshop for a number of years, as its units are much more convenient, especially in the fine measurements required in our class of work. We have also published our catalogues of scientific apparatus wholly in the metric system for a number of years, and find that this departure is very much appreciated by the scientific men with whom we deal. There is, however, a great disadvantage from a business standpoint in having two systems in use in this country. For example, we are requested to bid on chemicals by weight. We hand in our estimate based on quantities of 500 grams. A competitor hands in a bid on similar articles based on quantities of 1 pound. The average man does not stop to consider that there is a material difference in weight between 500 grams and 1 pound. We are, therefore, placed at a disadvantage, as our prices appear to be higher than those of our competitor, although they may in reality be lower, gram for gram.

The use of the two systems in periodical literature makes it absolutely necessary for those desiring to make any use of the investigations of others to be perfectly familiar with the equivalents of the two systems, and able to carry in his mind the value of inches and fractions of inches in millimeters, and *vice versa*, a wholly needless and time-consuming operation.

As it is without doubt only a matter of a comparatively short time when the principal nations will adopt the metric standard, it would seem to be to the utmost advantage of the United States to hasten the day by every possible means.

Yours truly,

BAUSCH & LOMB OPTICAL CO.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.*To the Secretary :*

* * * In the matter of the metric system, and your circular covering the questions discussed January 17, 1902, the points where I should take issue with the decisions of the committee would be the replies to 3, 6, 7 and 9.

In answer to Question 3, I would say that there are many more valid objections than the one presented in that question. The meter is too large as a unit and a millimeter is too small for uses in the average manufacturing process. The use of the decimal point on drawings and the use of dimensions expressed in decimals is exceedingly inconven-

ient. The scale of drawings using the metric system is much less convenient than the scales which are derivable from our present units. My answer therefore to Question 3 would be "Yes" instead of "No." With respect to the fourth question, it does not appear to me that any objections but the one urged in No. 3 is affected by it. The additional objections which I have urged above, and which are not inclusive of everything that could be urged, are not affected.

Question 6 begs the question at issue. This question is the existence of the expense and confusion it would entail upon manufacturers. Granting that the answer to Question 3 is not what the circular implies, the recommendation of the change as a compulsory matter would not be desirable for the reasons that I have advanced and others.

In Question 7, if it were not the case that some people thought the change desirable, it would be without meaning to have the National Government enter the thin edge of the wedge. There is much productive business in the country bearing no relation to the general Government, and those establishments which catered to or supplied both the Government and general public would be put to the expense of carrying everything in double standard.

The Navy Department, for instance, has certain standards of its own in certain lines, which must be conformed to by those who supply the Navy, but which are without meaning to other concerns working for a different set of patrons.

It does not appear to me that the adoption of the governmental departments of the metric and decimal standard would necessarily carry with it its adoption within a reasonable time, without legislation to compel it. It is the objections to compulsory legislation in the matter which constitute the objection to the whole principle of forcing an inconvenient unit. The metric decimal system is already legitimized and anybody can use it who wants to. The object of legislation is to compel people to use it who don't want to do so without a pressure coming upon one end of their business interests. It is true that a large number of computations would be facilitated by the use of a decimal system, but it is a pity to force the advantages of decimal methods at the expense of the compulsion of the use of the inconvenient metric unit as a feature of that alteration.

Very truly,

F. R. HUTTON,

*Professor Mechanical Engineering,
Columbia University.*

NEW YORK, February 13, 1902.

THE PENNSYLVANIA RAILROAD COMPANY.

PHILADELPHIA, February 10, 1902.

To the Secretary:

* * * In giving my views I would state that I am heartily in accord with adopting the metric system of weights and measures in the United

States. I do not believe it would create any embarrassment, and certainly would be a great benefit. The comparison between our present system and the metric system is about equal to dollars and cents as compared with shillings and pence, and I will therefore remember to vote to approve of any movement which will promote the universal introduction of the metric system, to take effect in the shortest possible time that will create the least confusion and expense. I do not see that it is necessary to defer the matter from any standpoint within my range of experience and knowledge.

Respectfully,

JOSEPH T. RICHARDS, *Engineer, M. W.*

PENNSYLVANIA RAILROAD COMPANY, BROAD STREET STATION.

To the Secretary :

In response to yours of the 7th, I have carefully read the report dated January 22, 1902, of the special committee of the Franklin Institute relating to the metric system, and think that the committee has stated the case in a very conservative way. The subject is such a comprehensive one that I cannot well enter into a discussion of it by letter. I think, however, that the Franklin Institute should put itself upon record by the adoption of the resolutions suggested by the report of the committee above referred to.

Yours truly,

THEO. N. ELY.

PHILADELPHIA, February 18, 1902.

R. D. WOOD & Co.

PHILADELPHIA, February 4, 1902.

To the Secretary :

Referring to your circular letter of the 1st inst., we agree heartily with the report of the special committee of the Franklin Institute of the advisability of adopting the metric system of weights and measures in the United States.

It would be most satisfactory to have the National Government make the metric system the only legal system throughout the United States, provided that sufficient time, say five or ten years, were given before it became compulsory, so as to permit of the different trades adjusting themselves to it.

Yours very truly,

R. D. WOOD & Co.

FERRACUTE MACHINE COMPANY.

BRIDGETON, N. J., February 17, 1902.

To the Secretary :

The writer must confess that he is "on the fence," so to speak, in regard to the metric system. He fully appreciates the principal reasons

for adopting it, which are its systematic arrangement, and the facility it gives for easy computation; also the fact that many other nations are adopting it, and he thoroughly believes in international unity in all directions.

The principal reason against the metric system is that it is founded upon the abominable base of ten, and it seems to the writer that the world is progressing so fast now that possibly within this century we shall be able to start the only decent and proper base for all numerical work, sixteen. On this the whole world could found an entirely new system of weights and measures, which would be entirely permanent. A change of this kind would probably not be so difficult to make (if taught for a few years in the schools along with the old system) as many people may imagine. When we get it we will save an enormous deal of figuring, and have a really scientific system; and it is bound to come some time. Shall we wait?

Yours very truly,
 FERRACUTE MACHINE COMPANY,
 per OBERLIN SMITH, *President*.

NEW YORK SHIPBUILDING COMPANY.

CAMDEN, N. J., February 18, 1902.

To the Secretary:

I regret to advise you that I have not read the report of the special committee on the metric system, which will be laid before the Institute on the 19th, and do not know just what is proposed. Under the circumstances I do not see that I can well render an opinion, excepting to state that no resolution of the Franklin Institute or any other such organization will bring about the use of the metric system. The ones particularly affected are the manufacturers, whose standards are all prepared under the duodecimal system; any change to a decimal system would mean to such manufacturers a very great confusion for a number of years, and while I am sure every one would be pleased if all our measures were under the metric system, it becomes a financial question rather than a theoretical one.

I have serious doubts as to whether the manufacturers are suffering sufficiently under the duodecimal system to care to encourage the expense of the change. I do not express this as a final view, but without serious consideration and without knowing exactly of what you purpose.

Very truly yours, HENRY G. MORSE, *President*.

THE LINK-BELT ENGINEERING COMPANY.

NICETOWN, PHILA., March 19, 1902.

To the Secretary:

We have gone over the report of the special committee on the metric system with care and wish to most heartily endorse the con-

clusions arrived at. We consider it of the utmost importance that the inevitable change to the metric system be inaugurated at as early a date as possible, and adverse opinion seems to be of no value whatsoever. The advantages to be derived from the metric system's adoption are clearly manifest, and opposition to a movement of this kind would seem futile, as, at best, it can only mean a trifling postponement and not, in any way, prevent its ultimate adoption.

Yours very truly,

THE LINK-BELT ENGINEERING COMPANY,

J. M. DODGE, *President.*

LIBRARY BUREAU.

BOSTON, August 12, 1901.

To the Committee of the Franklin Institute on the Metric System :

* * * We have been interested in the introduction of the metric system since 1876, Mr. Dewey, the former president of the Library Bureau, having been president of the Metric Bureau, established in 1876, which has been given up because of lack of financial support. We have continued to use the metric system from the beginning of our manufacturing, not only because theoretically we believe it to be superior, but in practice a very decided economy ; *e. g.*, in a comparison of weights and sizes of different thicknesses and grades of paper-stock we make them minutely as against long series of figures in the English. In our wood-working our men work to a closer degree of accuracy with no difficulty. Altogether we have continued to use the metric system in all our manufacturing because we find it is a direct saving.

Very truly yours,

H. E. DAVIDSON,

President.

BULLOCK ELECTRIC MANUFACTURING COMPANY.

CINCINNATI, O.

To the Secretary :

I beg to acknowledge your circular letter of the 1st, calling our attention to the report of the special committee appointed to consider the feasibility and advisability of adopting the metric system of weights and measures in the United States.

While we fully agree with the replies to the questions as shown by appendix attached to the committee's report, we would prefer that this change not be insisted upon for at least a year or two hence, and presume that even though favorable action should be taken at this time, it would be at least two or three years before it would come generally into use.

There is no doubt but what there would be many advantages in having the system a standard of this country, and there is no doubt also but what the change from the present system of weights and measures would involve the manufacturing concerns in very large expense. When it is decided to make the change, notice should be sent to manufacturers as far in advance as possible to enable them to prepare for these changes. More or less confusion is bound to develop in making the change, but this cannot be avoided.

We will be pleased to be kept advised in regard to the progress made, and beg to remain,

Yours very truly,

FRANK G. BOLLES,
*Manager Advance Department, Bullock
Electric Manufacturing Company.*

J. A. FAY & EGAN COMPANY.

CINCINNATI, February 7, 1902.

To the Secretary :

Your circular letter of the 1st inst. we have at hand and noted. We have carefully reviewed the questions discussed at the meeting of your sub-committee of January 17, 1902, and it leads us to express ourselves as being exactly in accordance with the answers that were agreed upon at that time, with the exception of Question 8. We believe there would be serious confusion in changing from one system to another in a shop or institution as large as ours, unless the bulk of the tools were discarded and the changes made all at once. We would have to use both standards for a long time to come, because of the vast amount of repairs that it is necessary for us to furnish repeatedly for machines that have been in existence for a good many years. Still, we probably would not let this matter stop us from adopting the metric system provided it was to be recommended and put into practice. * * *

Yours truly,

J. A. FAY & EGAN COMPANY.

WILLIAMS, BROWN & EARLE.

PHILADELPHIA, February 4, 1902.

To the Secretary :

In reply to your favor of the 1st inst., we would state that we entirely approve of the resolutions proposed by the special committee, "that the metric system of weights and measures should be adopted by the United States Government as the sole standard in its various departments at as early date as possible." It seems strange that the United States, one of the most progressive of nations, should be so late in the adoption of the metric system as a measure of weights and lengths.

The longer such a change is deferred the more difficult and expensive becomes its adoption ; we, therefore, should thoroughly approve of the United States Government initiating an early movement so as to make the change without interfering with the public service.

Yours respectfully,

WILLIAMS, BROWN & EARLE.

GOULD & EBERHARDT.

NEWARK, N. J., February 10, 1902.

The Franklin Institute :

* * * Relative to the matter of the metric system, we beg to say that we believe it would be a very good thing if some standard system of weights and measures similar to this could be adopted and universally used among all civilized countries; but so far as making its use compulsory, we think it will be a long time before this will be possible, on account of the great amount of money already invested in tools, instruments, etc., which are graduated by our present system. We think, however, the time is coming, but it means slow work, and the public will have to be gradually educated up to it.

Yours very truly,

GOULD & EBERHARDT,

FRED. L. EBERHARDT.

STANLEY ELECTRIC MANUFACTURING COMPANY.

PITTSFIELD, MASS., February 10, 1902.

To the Secretary :

* * * We agree with the resolves of the Institute and approve any movement which will permit the uniform introduction of the metric system, and we believe that the National Government should enact such laws as will ensure the adoption of the metric system of weights and measures in its various Departments.

Yours respectfully,

STANLEY ELECTRIC MFG. CO.,

R. W. POWER, M.E.

To the Secretary :

* * * No scientific man should be lukewarm in advocating the adoption of the metric system of weights and measures, and I think that any business man who should set himself seriously at work to estimate the time lost by the employment of the English measures where the French system could be used, would become inevitably an ardent advocate of a change to the metric system. * * * The English system is greatly supported by the rule of thumb. The best

examples of this method is that employed by the average photographer, who mixes his solutions by means of complex quantities approximately expressed in avoirdupois or troy weights.

Very truly,

JOHN TROWBRIDGE.

CAMBRIDGE, MASS., February 27, 1902.

THE AMERICAN JOURNAL OF SCIENCE.

NEW HAVEN, CONN., February 8, 1902.

To the Secretary:

To my regret I cannot be present at the meeting to be held at the Franklin Institute on the 19th, nor can I attempt to give my views in detail on the introduction of the metric system. I take pleasure, however, in expressing my most hearty sympathy with this movement and my endorsement of the report of the sub-committee as given on the enclosed sheet.

Very truly yours,

E. S. DANA.

THE MORGAN LABORATORY OF PHYSICS, UNIVERSITY OF PA.

PHILADELPHIA, February 6, 1902.

To the Secretary:

I am in receipt of the report of your committee on the subject of the metric system. * * * I endorse the report in every detail.

Respectfully yours,

ARTHUR W. GOODSPEED.

BROOKLYN, N. Y., December 16, 1901.

The Committee of the Franklin Institute on the Metric System:

In reply to your favor of December 13, I understand that you have a copy of my paper read at the meeting of the A. S. M. E. I have no other paper that I could furnish you.

There was no further discussion on this subject, which I regretted at the time, as I had hoped that the question of either adopting the metric system or some other decimal system—it makes little difference to me which—would be taken up and discussed, and that this might bring us a little nearer towards the desired end.

The system which was the object of my paper was, of course, merely a suggestion or a query as to the advisability of recommending same, being convinced that the adoption of the metric system, on account of its incommensurate relation to the English yard, will present almost insurmountable difficulties. Most of our tools, jigs, gages, etc., would have to be changed at an enormous expense, as it would not be practical

to adhere to the dimensions we are now using and express them in ten-thousandths of millimeters.

The ease with which values in the proposed system could be converted into values of the metric system would enable the two to exist side by side without interfering with each other.

Anybody will admit that our present system of measuring solids and weights should be revised anyway, and although I added the "vol" and the "pon" in order to make the system complete, I am in favor of adopting the liter and the kilogram in any case.

I was very glad to hear that the Franklin Institute had taken up this matter and I express the hope that something definite will be decided by your committee. If nothing else can be settled upon, let us have the metric system by all means, for the longer we wait the harder it will be for all of us later on.

Yours truly,

F. F. NICKEL.

To the Secretary :

* * * I hope sincerely that the report of the special committee on the adoption by the United States of the metric system will be carried, as it is directly in the line of progress, and will prove as great an improvement as our decimal system of money is over the English currency.

ISAAC NORRIS.

PHILADELPHIA, February 7, 1902.

RUMFORD FALLS POWER COMPANY.

RUMFORD FALLS, MAINE, March 11, 1902.

To the Secretary :

Noting in our March JOURNAL the report of the special committee on the metric system, I am prompted to write that recently I enquired of my children if it was taught to them in the schools, and they did not even know what the system was. I then enquired of our Superintendent of Schools, and he replied that the tables were included in the text-books among other tables of weights and measures, but as the system is not in popular use, it probably received less attention in the classes than even its relative and small proportion of treatment in the text-books. He said also he found little about it in the educational press as a live educational subject. Does not this suggest two neglected opportunities, elementary and fundamental ones, for teaching and increasing the use of the metric system, viz.: First, getting the text-book writers and publishers to give it a larger place; and, second, to publishing more about it in the popular teachers' papers of every grade? I find that many are almost ignorant of the system; they regard it as something foreign; anyway, it is not familiar. I have sent to our

Superintendent my chart, issued by the American Metrological Society, which I regard as excellent. Please refer this to some one of the special committee of the Institute, or use it otherwise as may best help advance the use of the metric system.

Yours very truly,

CHAS. A. MIXER,
Res. Eng.

ENGINEERS' AND ARCHITECTS' CLUB OF LOUISVILLE.

LOUISVILLE, KY., December 21, 1901.

To the Secretary :

I respectfully request that you use this writing as authority for casting my vote strongly in favor of the metric system of weights and measures. I would make it compulsory and in force as early as possible.

Yours truly,

THOMAS P. SHANKS.

PHILADELPHIA, February 7, 1902.

To the Secretary :

* * * I am in sympathy with the resolutions, and indorse the same.

Yours very truly,

HORACE PETTIT.

Messrs. the Franklin Institute, Philadelphia, U.S.A.

SIRS :—I just received the February 21st number of *London Engineering*, and noted with the greatest interest that your Institute took so decisive a step in relation to the introduction of the metric system into your great republic, which we Dutchmen can never forget is the birthplace of John Lothrop Motley, to whom we owe so great a debt.

I am glad to see that the name of the great Franklin will be united to the great scheme of introducing the metric system and supplanting the barbarous, incoherent mass of weights and measures which is now prevalent in Anglo-Saxon regions. I am sure that if he had lived to-day, he would have been the first to propose the measure you have just taken.

What especially rejoices me is that not only scientific men like Mr. Jesse Pawling, Jr., signed the report issued by the committee, but that practical men like James Christie and others, joined in the recommendation of the metric system. Scientists, as physicians, chemists, have, even in Great Britain, adopted metric measures and weights, and so I was not at all astonished to see their names. But every technical man must feel what heavy expenses and great trouble will accompany the introduction of metric measuring into shop-work. The more it is to be appreciated that practical men join in the demand, but I am sure that after a purgatory of confusion the reward will not remain behind.

The cry for the metric system has been heard in Great Britain as well as in the United States, and I am glad to add that there also the cry is heard not only from scientists or laboratory workers, but also from practical men like Harvard Biles, Archibald Denny, etc.

Allow me, gentlemen, one little remark in relation to Questions 8 and 9 of the Appendix to the Report. There will be, of course, a little confusion accompanying the introduction of the metric system; but I beg to remark that the sooner the introduction is carried on, the less will be the confusion. There is now a whole stock of machinery, etc., which in time wants repair; bolts and nuts, boiler plates, wheel-tires, and so on, want periodical renewing, and in the majority of cases the articles dimensioned in feet and inches cannot be supplanted by metrically dimensioned ones. So, as long as this stock is not yet exhausted, a double set of lathes, of rules and regulations will be necessary; double sets of rolls for sections will be necessary for steel works for rolling the old and new sections. But this already large stock is daily rapidly increasing, and that is, in my opinion, the reason that, if it will be resolved to introduce the metric system, the sooner it will be done the better. Besides that, I think that for your foreign trade the time will not be far that manufacturers will be set with against, to accept of their export business, the metric system, as otherwise they cannot take up the competition against German, Swiss and French manufacturers.

I beg to call your attention to the splendid work the Germans have already done with their book for sections, "*Deutsches Normalprofil-Buch für Walzeisen*," and also the work done in standardizing screw-threads, the "*Internationales Gewindesystem*," based upon the metric system, unites the advantages of the best two other systems—the Whitworth and the Sellers.

In expressing my best sympathy for the measure you have taken and the hope that it will soon bear fruit, I conclude by calling myself,

Most respectfully yours,

H. VAN MEERTEN, M. I. N. A.,

Late Chief Constructor, Dutch Navy.

BUITENZORG (JAVA), March 20, 1902.

P. S.—Before finally concluding, I beg to call your attention to the C. G. S. system, which has already done so much good service in the electric work, and which now Mr. A. Hauser, late Chief Constructor of the French Navy, has proposed for the standard to be used in ship building and machine building. His views are published as well in the Bulletin of the Association Technique Maritime as in the Transactions of the Institution of Naval Architects, and, if accepted, will in future considerably facilitate the study and working out of mechanical problems. * * *

H. VAN M.

THE DECIMAL ASSOCIATION.

BOTOLPH HOUSE, EASTCHEAP,

LONDON, E. C., February 14, 1902.

To the Secretary:

* * * I hail with gratification your attempt to make the advantages of the metric weights and measures known in the United States.

I will not burden you with a long narrative of the progress of the movement in England in favor of the adoption of the metric weights and measures. I may summarize the growth of strength of that movement in the fact that we can now count upon the support of 260 Members of Parliament, absolutely pledged to vote in favor of our object, whereas three years ago the result of a strong canvass only showed ninety-six whose favorable vote could be counted upon.

Barely a month passes but what some of our consuls abroad draw attention in their official reports to the loss of trade which we are suffering because our weights and measures are not understood in most of the continental countries. Sixty per cent. of our foreign trade (excluding British possessions) is carried on with countries which use the metric weights and measures.

Yours faithfully,

E. JOHNSON, *Secretary.*

VICTORIA WORKS.

RUGBY, February 17, 1902.

To the Secretary of the Decimal Association, Botolph House, Eastcheap, London, E. C.:

DEAR SIR:—In reply to yours of February 14th, we should be much obliged if you would convey to the Franklin Institute, of Philadelphia, U.S.A., the following by way of communication from us on the subject in question:

We have carefully considered the questions asked for in the Appendix, and can fully subscribe to the answers agreed upon.

The suggestion made in Question 8 that existing tools and gages can be retained, and can be used concurrently with those designed to the metric units, is precisely the system we have followed for the last nine or ten years without the least difficulty whatsoever, notwithstanding the fact that, owing to our special circumstances, tools and gages to English units are still in use and that without creating any confusion. We have, therefore, no misgivings as to the soundness of the views expressed in Question 8.

Yours faithfully,

WILLANS & ROBINSON, Limited.

HECLA WORKS.

SHEFFIELD, February 17, 1902.

To the Secretary:

* * * We thoroughly agree that the adoption of the metric system would be a great saving in time and money. * * *

Yours faithfully,

R. A. HADFIELD.

THE WALDORF-ASTORIA.

NEW YORK, May 10, 1902.

To the Committee of the Franklin Institute on the Metric System.

GENTLEMEN:—I thank you for your letter of the 26th April with enclosure—resolutions and report of the Franklin Institute approving of the adoption of the French metrical system. I am very glad that the Franklin Institute has given the weight of its support to the reform which seems now imminent. It will, I believe, be most beneficial to America, and its adoption here will, I am sure, be very effective in accelerating its adoption in Great Britain and the British Colonies.

I remain, yours faithfully,

KELVIN.

COMMITTEE ON COINAGE, WEIGHTS AND MEASURES.

House of Representatives, U. S.

WASHINGTON, D. C., February 24, 1902.

To the Secretary:

I desire to thank you for your letter of February 24th, containing information that at a stated meeting of the Franklin Institute, held Wednesday, February 19, 1902, the report of the special committee appointed to consider the feasibility and advisability of the adoption of the metric system reported favorably as to its adoption, and that the report was adopted. The resolution adopted by the Institute endorses substantially the provisions of the bills now pending in the committee.

Very truly yours,

J. H. SOUTHARD,

*Chairman Committee on Coinage,
Weights and Measures, H. R.*

Fifty-seventh Congress, first session, H. R. 123, Report No. 1701.

In the House of Representatives, December 2, 1901, Mr. Shafroth introduced the following bill, which was referred to the Committee on Coinage, Weights and Measures and ordered to be printed. April 21,

1902, reported with amendments, referred to the House Calendar, and ordered to be printed.

A BILL

To adopt the weights and measures of the metric system as the standard weights and measures in the United States.

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That on and after the first day of January, nineteen hundred and four, all the departments of the Government of the United States, in the transaction of all business requiring the use of weight and measurement, except in completing the survey of public lands, shall employ and use only the weights and measures of the metric system; and on and after the first day of January, nineteen hundred and seven, the weights and measures of the metric system shall be the legal standard weights and measures of and in the United States."

COAL PRODUCTION OF THE UNITED STATES IN 1901.

The United States Geological Survey has prepared a preliminary report upon the production of coal in the United States in 1901, based upon the returns representing 97 per cent. of the entire output, which show that 292,240,758 short tons were mined during the year, valued at \$348,813,831. As compared with 1900, when the output amounted to 269,881,827 short tons, worth \$306,891,364, this represents an increase of 22,358,931 short tons, or 8 per cent. in quantity, and of \$41,922,467 or 13.6 per cent. in value. The production of Pennsylvania anthracite showed a phenomenal increase—namely, from 51,221,353 long tons (equivalent to 57,367,915 short tons) in 1900 to 60,242,560 long tons, or 67,471,667 short tons, in 1901. This represented a gain of 17½ per cent., the largest percentage of gain made by the anthracite trade in 20 years. Part of this increase in 1901 was due to a decreased output of anthracite in 1900, as compared with 1899, as owing to the historic strike of 1900 the output that year was reduced by over 2,500,000 tons. The average price for the marketed anthracite coal—that is, the product shipped to market or sold to local trade, and exclusive of the colliery consumption, which amounted to about 10 per cent. of the total—was \$2.05, the highest figure obtained since 1888.

The production of bituminous coal, lignite, cannel coal, etc., including a small amount of anthracite from Colorado and New Mexico, increased from 212,513,912 short tons in 1900 to 224,769,091 short tons in 1901, indicating a gain of 12,255,179 tons, or about 6 per cent. The value of this product amounted to \$236,309,811, as compared with \$221,133,513 in 1900, an increase of \$15,176,298, or a little less than 7 per cent. The price of the bituminous product did not show any material advance in 1901, the average being about 0.8 cent higher than in 1900.

The preliminary report issued by the Inspector of Mines for Great Britain shows that the production of coal in the United Kingdom last year was 219,037,240 long tons, a decrease of 6,132,923 long tons from 1900. Reducing the

product of the United States to the same unit, it is found that it amounted to 260,929,248 long tons, which is 42,439,760 long tons, or nearly 20 per cent. more than that of Great Britain. The coal output of her colonies and dependencies (including India) aggregated in 1900 about 17,000,000 long tons, so that taking all the British Empire as one producer, it still falls short of the coal product of the United States last year by from 20,000,000 to 25,000,000 long tons. Our coal production last year was nearly 80 per cent. larger than Germany's, nearly seven times that of Austria-Hungary, and more than eight times that of France.

POPULAR ERRORS IN METEOROLOGY.

Professor Gannett, of the United States Geological Survey, has a paper in the Bulletin of the American Geographical Society which treats of popular errors in meteorology and geography, entitled "Certain Persistent Errors in Geography." A few of his points are summarized in what follows:

Forests and Rainfall: An example of the persistence of error is the idea that the presence or absence of forests has an influence on the amount of rainfall. Some keen observer long ago detected the fact that forested regions enjoyed a heavier rainfall than those not forested, and jumped to the conclusion that rainfall was produced by forests, and that the removal of forests diminished the rainfall. Looking over the earth he found many treeless desert regions and forthwith instanced them as frightful examples of men's wastefulness. Syria, Northern Africa, parts of Italy, are often quoted as illustrations of man's destruction of climate. In reply, man can certainly plead not guilty. The geography of this Mediterranean region, the configuration of land and water, and the direction of the prevailing winds, are such as to give it a light rainfall—forests or no forests. The situation is really this: Want of rain prevents the growth of trees; want of trees does not prevent rain. **Forests and Floods:** Another persistent error is the belief that floods in our rivers are more frequent than formerly because of the cutting down of forests in their drainage basins. It is probable that the clearing of land by cutting away forests and undergrowth does change the regimen of streams, increasing their flood-height and diminishing the flow at low stages. In other words, water probably runs off or evaporates more rapidly from bare ground than from ground covered with forests. But where the forests are cut away the ground is seldom left bare; it is cultivated or quickly becomes covered with bushes which hold the water quite as effectively as forests. The main fact is, however, that the floods in our rivers are no greater or more frequent now than in the past.

Climates and Ocean Currents: The well-known mild climate of the north-west coast of America is commonly attributed to the Japan Current. The Gulf Stream is supposed to have the same influence on the western coasts of Europe, etc. But can it be supposed that the Japan Current, however warm it may be when it leaves the tropics, retains any appreciable excess of heat after a journey of 6,000 miles in northern latitudes? As a matter of fact, no trace of this current reaches the shores of North America. In the North Atlantic the condition is much the same. The Gulf Stream disappears as a current long before the British Isles are reached.

Death Valley.

BY PROF. OSCAR C. S. CARTER.

Judging from the many highly sensational stories and frequent references to Death Valley, there is evidently a popular interest in that dreaded locality, which is in part explicable by the name it bears. The stories published are, as a rule, of little value, and give no idea of the climate, topography, fauna and flora, of a more absolute and arid desert than the Sahara. Our great deserts of the southwest have been but little written about by geographers and travelers, and it is only recently that accurate official reports upon them have been made. Captain Clarence E. Dutton, in his report on the Grand Cañon, gave a description of the deserts of Northern Arizona. Captain Gaillard, of the Mexican Boundary Commission, has given us, in a popular magazine, probably the best article that has as yet been written on an American desert. He was well qualified to write, because he traversed the entire region from the Rio Grande to the Pacific, erecting monuments to mark the boundary between Mexico and the United States. Mr. W. J. McGee, Chief of the Bureau of American Ethnology, who recently made the journey through Southern Arizona and Mexico, to study the Seri Indians, who live on the Isle of Tiburon, in the Gulf of California, has given us a fine description of the desert in his report and in separate articles in the "Journal of Geography." A valuable article on the American Desert, by Robert T. Hill, has just appeared.

The above descriptions stand out like oases in a barren desert. These deserts of the Southwest, which take in the southern parts of California and Arizona, are called the Colorado Desert, from the river of that name which empties into the Gulf of California. They are hotter, dryer and more arid than the Sahara, as proved by the official records of the Boundary Commission. The early days of '49 saw much suffering and hardship endured by the overland trav-

elers across the desert to California, and one of the most pathetic stories of suffering ever told was narrated by the survivors of a Death Valley party. They followed the old Santa Fé trail through New Mexico and Arizona, the same that the Santa Fé Railroad now parallels. Those who traveled north from Mexico across the Colorado Desert to California shared even a worse fate, as their bleaching bones along the desert testify. In September, 1849, a party of 500 emigrants left Utah for the land of gold. Their household goods were carried in the typical prairie schooners drawn by oxen. They left full of hope and good cheer, but in time a dispute arose as to the route and the party divided; some went east to strike the trails between Santa Fé and the Pacific, but the main party forged ahead to cross the land of the mirage and thirst. When they reached the plateau country, the land of the mesa and cañon, their canvas-covered wagons were useless. The green of the upland and meadow, so familiar in their eastern home, was wanting here; instead long lines of plateau and mesas with steep precipitous slopes met their view at every turn. These glaring red table lands could not be crossed unless they knew the country, so they packed their belongings on the backs of the sturdy oxen and trudged wearily along across the burning arid wastes. One by one the oxen perished and starvation stared them in the face; some of the more vigorous pushed ahead and reached Death Valley, where they perished miserably. It is said that one poor fellow, left for dead, recovered sufficiently to crawl on his hands and knees more than two miles after his companions and then perished. The remnant of the expedition crossed the valley at a narrow part and lived for days on a jelly made from boiled ox-hide. Gaunt and emaciated they slowly climbed the mountains and the survivors were nursed back to health on a ranch in the fertile valley to the westward. The valley takes its name from this and other sad experiences.

It is known that men exposed to the sun's direct rays are occasionally made insane, and it is said that one man drove in on a load of borax to the borax works which are located in the valley, during a particularly torrid day, and expired

quickly, rigidly grasping in his stiffened fingers a water canteen. Birds in summer rarely try to fly across this alkaline expanse, and when they do, frequently drop dead in mid flight.

The animals, such as are found there in the summer, are mostly nocturnal, as might be inferred from the prevailing intense heat. Horned toads and other lizards and snakes constitute the fauna. Cooked meat spoils overnight, and raw meat dipped in brine is cured in a couple of hours. The bitter streams of alkaline waters which start from the surrounding mountains are eagerly sucked up and disappear before they flow far into the parched soils of the desert. And yet this region is well known; much better known than many other parts of this country. Occasionally an exploring expedition visits it, prospectors often wander into the valley in search of gold, and one lonely miner kept his cattle high up the mountains for nearly a year. Gen. Frederick Funston, before he had won his honors in the Philippines, was assistant to a Government botanical expedition, which in 1891 studied the flora of the desert and the surrounding mountains. The work in the valley was mostly done in the cool of winter, while the flora of the mountains was studied during the warm summer months.

Probably the first scientific expedition to the valley was made by the California Boundary Commission in 1861. Lieutenant Birnie, of Wheeler's Geological Survey Expedition, crossed it several times and made his camp in it for awhile. In 1891 the Botanical Expedition, headed by Frederick Vernon Coville, with Frederick Funston, assistant, explored this region. It was directed by Hart Merriam. This expedition was made with the co-operation of the U. S. Geological Survey and Signal Service, and was continued by Mr. John H. Clery of the Weather Bureau, under the direction of Chief Mark Harrington. It is to the reports of these gentlemen and independent observers that we are indebted for most of the information we have about the valley.

Location.—Death Valley lies in Southeastern California, not far from the boundary line of Nevada and about 50 miles due east of Owens Lake. It lies between mountains

in a section of country east of the Sierras. It is enclosed between the Funeral and Amargosa Ranges on the east, and the Pinto and Panamint Ranges on the west. These ranges are higher than the White Mountains of New Hampshire, and some of the peaks (as the Sentinel) are 9,856 feet high. They are not parts of the Sierra Nevada Range. The valley has a length of about 75 miles from northwest to southeast, and at the bottom is only 12 to 15 miles wide at the widest part. Opposite the borax works it is only 6 miles wide.

Below Sea Level.—The valley is one of the few areas in this country that are situated below the sea level. The barometric observations of Lieutenant Birnie show that a large part of the valley is 100 feet below sea level, and some parts much less. Williamson states that the valley is 175 feet below sea level. No doubt parts of the valley are much lower than these figures. There are some sinks along the Colorado River in Southern California which are also below sea level, but such localities are few in the United States.

Origin.—This valley was evidently occupied at one time by an inland lake of alkaline water, such as the Carson, Winnemucca and Humboldt Lakes of Nevada are to-day. As it slowly evaporated, the water became bitter from the excess of mineral matter until finally it disappeared altogether, leaving a deposit of salt, borax, etc., which even at this late day can be seen along the eastern border where the slight rainfall has not carried it away.

Borax Works.—Borax is an important salt in the arts. On the eastern side of Death Valley is located the Pacific Coast Borax Company. Some years ago they fenced in 30 acres, to which they gave the rather inappropriate name of Greenland Ranch. In order to raise what crops were needed for food, water was brought from the mountains in barrels and stored in two small reservoirs. With this supply they irrigated and raised several crops of alfalfa a year; by irrigating constantly, a few cottonwood and fig trees were grown. When the works were first started, 40 men were employed, who did not stay in the valley in summer. Their season began with September and ended in June.

Climate.—In winter the climate is not hard to bear. On the highest surrounding mountains it is quite cold and snow falls. In the valley it is comfortable. The fauna changes in the winter and jack-rabbits and cottontails visit the valley, as do migrating birds, such as ducks. This wide range of temperature in winter and summer is not unusual. At Yuma, in Southwestern Arizona, the temperature in winter falls to 27° Fahr., but in summer it is one of the hottest places in the United States. Even the neighboring Piutes cross the mountains and visit the Death Valley in winter. Early spring and late autumn are not hard to bear, although spring begins earlier there and scarcely any rain falls.

It is the hot stifling summer months that are unbearable. They sap the strength and vitality of the strongest. There was one employé of the Weather Bureau, Mr. John H. Clery, who stuck to it and stayed through the summer, under the most adverse and trying circumstances. His assistant was prostrated by the fearful heat and had to return to Keeler for treatment. Clery made his headquarters at the foot of Funeral Mountains, in a building owned by the borax works. He stayed there five months in the hottest part of the year. The soil near the station was a shifting white sand. No vegetation, except an occasional mesquite bush. The highest temperature reached was 122° in the shade. This temperature was reached for several days, and for three successive days in June, the hottest days he experienced, showed a maximum temperature of 120° F. In July, the hottest month, an average daily maximum of 116° was reached; although this maximum was exceeded in the desert of the Colorado and in parts of India, the average is higher than the averages of those places. We often hear higher temperatures quoted for deserts, but fail to consider they were not taken under official auspices, and that the instruments, not being properly shaded, were affected by reflected and radiated heat. Some of the temperatures quoted for deserts are absurd.

Death Valley, however, is not the hottest place in the United States. The highest temperature ever recorded by

official instruments in the United States was at Mammoth Hot Tank, California, in the Colorado Desert. There, in July, 1887, the temperature reached 128° F., in the shade, and on another occasion reached 126°. At Yuma, the highest official temperature was 118°. There they sleep out of doors, on roofs and porches, in summer, and work is done in the early morning hours before the sun comes up. Much higher figures have been quoted for Yuma, but they are not official. The writer found the Mohave Desert, in Southern California, in two different summers, and the Painted Desert, in Arizona, much too warm for comfort, and was reminded of the western stories of the army officer who had been stationed at Yuma for many years. Finally, he passed away, but returned from Hades to Yuma, for his overcoat.

Rains are not frequent in Death Valley, and curiously enough, the little rain that does fall generally comes down at night. For the entire period of five months, during which a record was kept and measurement was made with the rain-gage, not quite $1\frac{1}{2}$ inches of rain fell. Many of the showers were so slight that they were merely traces, not enough to be measured by a gage. Agriculture cannot be carried on successfully in the United States without irrigation when the rainfall is less than 20 inches per year. When we consider the fact that in Pennsylvania we have an average rainfall of about 40 inches a year, and that in Oregon the rainfall reaches 100 inches per year, we realize what a slight rainfall the Valley has. No records of the rainfall in winter were kept, but if we compare it with the surrounding deserts we can get a pretty good idea. Such a comparison would lead us to assume that the rainfall is from 3 to 4 inches per year. There are other deserts in the United States which in summer show even less rainfall than the Valley. Nearly all the stations in the Desert of the Colorado, in California, show less rainfall than the Valley. Contrary to usual opinion the atmosphere is not sluggish and calms are not common. The prevailing wind is from the south and it is frequent, but in summer it is like the breath from a fiery furnace. Comparisons of temperature with oases in the Sahara and desert places in India show

that Death Valley is much hotter and dryer, and although the maximum may be exceeded in parts of the Colorado Desert and in India, yet the averages are higher.

The cause of the small rainfall is easily understood. The location and topography are unfavorable for even a moderate rainfall. A valley below sea level, surrounded by mountains in an arid region, would not receive much rain. The vapor-laden winds from the Pacific lose their moisture when they are cooled in ascending the slopes of the Coast Mountains of California and the Sierra Nevadas to the westward. The moisture is precipitated as snow and rain long before these winds reach this valley. Hence, when they do reach it, they are already deprived of most of their moisture. It is a well-known fact that cyclonic and anti-cyclonic areas move from west to east; in other words, our weather moves from the west towards the east. Notwithstanding this fact, were it possible for any winds from the east or southeast to reach this valley, they would be dry winds, because their moisture would have been removed by precipitation in crossing the Rockies, and afterward the high plateau country of New Mexico, Northern Arizona and Utah.

CENTRAL HIGH SCHOOL, June 1, 1902.

SOME RECENT ELECTRIC FURNACE PRODUCTS.

Although the pulverization of metals in the electric furnace forms the subject of several patents issued in this country and abroad, but little is known of the practical operation of the methods or of the nature or use of the several products obtained.

The general method is simple in the extreme. A metal is heated either by the arc or by the passage of a heavy current through a column of reduced cross section, and is thereby brought to the temperature of volatilization. Vapors so produced are, in most cases, directly combustible in air, burning freely to oxide, or may be subjected to various reagents with corresponding variety in the products; or, finally, the metal may be collected directly in comminuted form in an inert atmosphere. The applications of the method embrace the manufacture of a whole series of pigments, abrasives, refined metals, and miscellaneous reagents.

In 1896, the Société Civile d'Etudes du Syndicat de l'Acier Gérard, of Paris, patented abroad a method designed primarily for the production of steel from iron by a modified Bessemer process, the principal feature of which was the comminution of the metal before subjecting it to a graduated blast

of air, the effect being, as in the converter, the oxidation of silicon, sulphur, phosphorus and carbon, and the conversion of the pig metal into steel. As one method of pulverization, the employment of the arc was suggested, the fused metal falling in a stream between the circuit terminals and collecting after passing through an air blast in the hearth of the furnace.

Later, a modified construction was adopted wherein a metal formed a short circuit between water-cooled terminals, and the air blast was projected against its surface at the point of maximum temperature; the vapor was thereby oxidized, and carried over to a collecting chamber forming a part of the furnace.

The substitution of other metals for pig iron suggested at once several modifications of this process, to wit: the comminution of lead for use in accumulators; the production of litharge by the concurrent oxidation of the lead; the production of zinc as a sublimate, or, in the presence of an air blast, of zinc white; the production of rich mattes of copper, or the pulverization of this metal as a preliminary to the extraction of the contained values; the production of powders of bronze, tin and aluminum, which enter in many ways into industrial processes; and finally the comminution of chrome—or tungsten—steels, to serve as abrasives.

An analogous procedure for the manufacture of white lead has been patented in this country to Messrs. Bailey, Cox & Hey. In this process the arc is struck from a tabular electrode to the surface of a mass of molten lead. Commingled vapors of water, carbon dioxide and acetic acid, introduced through the hollow electrode, are presumed to react with the vaporized lead to form commercial white lead; the function of the acetic acid in this process is not clear and its use is probably merely a relic of various prior methods operating at temperatures at which the acid is stable.

Messrs. Bredig and Haber have noted in the *Berichte* a curious phenomenon, which occurs when the arc is struck beneath the surface of the electrolyte, either acid or alkaline, to a lead wire cathode, or when high cathode current densities are used under these conditions; the metal is disintegrated, appearing as a cloud in the solution, and white lead may, it is said, be produced by merely injecting air and carbon dioxide. The method is, of course, not a commercial one.

Recently M. Barry, of Paris, patented a furnace for the commercial production of stannic acid. The molten metal is included as a resistance in the circuit, and the vapors as they escape from an orifice in the furnace cover are ignited by an air blast, and the dioxide collected. The Tin Electro-Smelting Company, Limited, of Paris, which controls this patent, is also marketing a series of pulverized metals, presumably made in an analogous manner. These are an impalpable powder of tin, known in France as *argentine*, and capable of giving, by simple rubbing, a burnished foil-like surface to paper; several grades of pulverized aluminium, the finest constituting the base of a new high explosive, and the coarser grades adapted for use in thermite reactions, as, for instance, the reduction of oxide of chromium, etc.; and pulverized lead, employed for the manufacture of minium, of white lead, and particularly for the production of sodium nitrite.—Clinton Paul Townsend in *Electrical World*.

Mining and Metallurgical Section.

Read at the Stated Meeting, held Wednesday, December 11, 1901.

Upon the Structure of Metals and Binary Alloys.

BY WILLIAM CAMPBELL, B.Sc. (Durham), F.G.S.

(*Concluded from p. 142.*)

In Group III no eutectic in the true sense of the word exists. The examples of this group are:

Bismuth and antimony.

Silver and gold.

When an alloy of gold and silver commences to solidify, dendrites comparatively rich in gold begin to form. The mother-liquor is enriched in silver. As the temperature falls, the dendrites continue to grow larger and larger, but as each coating of metal is less rich in gold than the one previous, and as diffusion (in the case of slow cooling) produces a uniformity of composition or an equilibrium in the dendrites, these latter become richer and richer in silver, till at the point where the whole alloy becomes solid they have the composition of the original alloy. Of course, if equilibrium is not established we get mixed crystals, or in other words the dendrites are richer in gold at the center than at the outside.

A fourth group might be added—where a compound is formed and we get two divisions:

(1) An excess of the first metal or the compound crystallizing out in the eutectic of this metal and the compound.

(2) An isomorphous mixture of the compound and the second metal.

To this group would belong antimony and silver and perhaps tin and silver. Thus this group is really a combination of Groups I and III.

Charpy groups together alloys with abnormal curves of fusibility. Amongst them are:

Copper and tin.
Copper and zinc.

Antimony and tin.
Zinc and silver.

TIN AND ZINC.

The cooling curve of the series (*Fig. 33*) is composed of two inclined branches meeting at 8 per cent. zinc. The

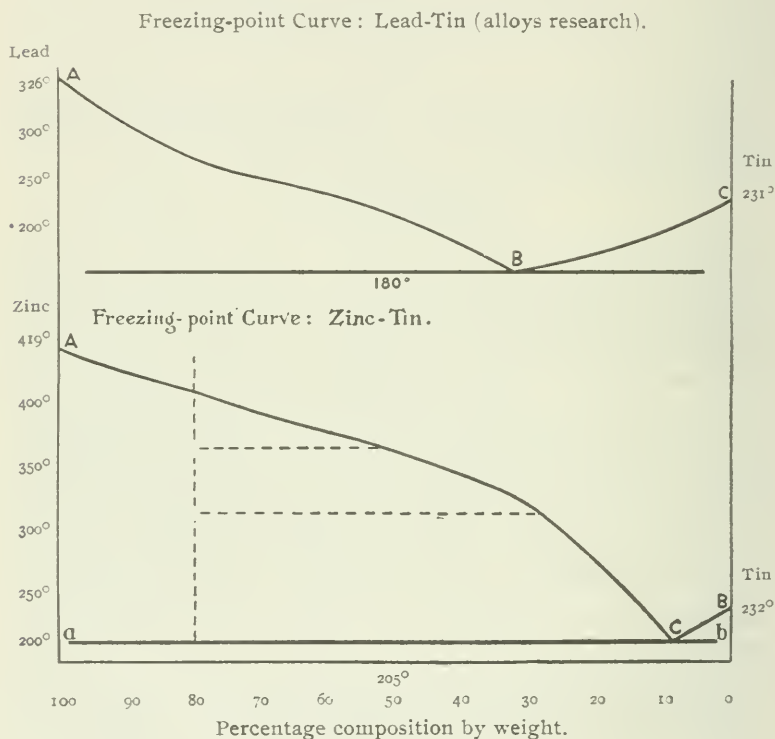


FIG. 33.

horizontal branch corresponding to the freezing of the eutectic occurs at 205° C., and extends from almost pure tin to almost pure zinc; in other words, as soon as a very small quantity of one metal is added to the other a eutectic is formed, for the concentration of the solid solutions formed is very dilute.

Then between tin and the eutectic alloy containing 8 per cent. zinc we find grains, and then dendrites of tin set in an increasing groundmass of eutectic. The solidification of the tin is marked by the break BC in *Fig. 33*, whilst that of the eutectic is denoted by the break bC . Below bC the alloys are solid; between BCb we have a mixture of solid grains or dendrites of tin in a liquid whose composition will depend upon the temperature.

Between zinc and the eutectic alloy we find grains, dendrites, and then long, attenuated, lath-like bodies of zinc surrounded by increasing amounts of eutectic. The solidification of the zinc is marked by the break AC , whilst that of the eutectic is denoted by aC . Then, as before, below aC all the alloys are solid. When an alloy cools down from the liquid state, it remains entirely liquid till its temperature reaches that of the curve AC . For example, take the alloy containing 80 per cent. zinc. At 390°C . the first grains of zinc begin to form and the mother-liquor is enriched with regard to tin. As the temperature falls, the zinc grains grow and the mother-liquor becomes richer and richer in tin. Thus at 350°C . it will contain about 47 per cent. of tin; at 300°C . about 72 per cent.; whilst at just above 205°C . it contains about 92 per cent. At 205°C ., that is, the temperature aCb , the mother-liquor solidifies and the temperature remains constant till the whole mass is solid; then the temperature falls normally in the solid mass. *Fig. 19* shows an alloy containing 20 per cent. zinc, 80 per cent. tin. The long, lath-like grains of zinc are seen with their distinct tendency towards parallel growth. *Fig. 17* would well illustrate the appearance of an alloy containing between 60 and 70 per cent. Zn.

LEAD AND TIN.

The cooling curve for these two metals, taken from the Report of the Alloys Research Committee (London), is shown in *Fig. 33*. It consists of two inclined branches meeting at the eutectic point, 68 per cent. tin, 32 per cent. lead. The horizontal branch corresponding to the solidification of the eutectic occurs at 180°C . and probably extends

further than shown, for it would appear in this case also that the concentration of the solid solutions formed was very minute. The meaning of this curve is the same as that of the tin-zinc series. Alloys containing more than 68 per cent. Sn remain liquid until their temperature reaches *C B*. At that point pure tin or almost pure tin crystallizes out of the mother-liquor and continues to crystallize out till the mother-liquor reaches the composition of 68 per cent. Sn, which it does at 180° C. At that point it solidifies as a eutectic of alternate laminæ more or less curved of lead and tin, without any fall in temperature. When solidification is complete the temperature falls normally. Alloys containing less than 68 per cent. Sn remain liquid till they reach the temperature of branch *A B*, when lead commences to crystallize out, enriching the mother-liquor in tin. Crystallization continues until the mother-liquor has a composition of 68 per cent. Sn at 180° C., when it solidifies as before.

The surface structures of these alloys when cast, and also when slowly cooled, give a good indication of their internal structure. *Fig. 20* shows the surface structure of the alloy 15 per cent. Pb; 85 per cent. Sn when cast. The large dendrites of tin, differently orientated, are seen standing out above the surface. The eutectic, in cooling and solidifying, has shrunk and sunk beneath the level of the dendrites, which thus stand out in relief. *Fig. 21* shows the surface of an alloy from the other end of the series. It contains Sn, 26 per cent.; Pb, 74 per cent. It is taken from a small ingot. In this case the dendrites are those of lead, which stand out above the level of the eutectic. The difference in size of the dendrites of tin and lead is great.

Fig. 22 shows the effect of copper upon common solder. Five per cent. of copper was added to the solder (2 Pb : 1 Sn) giving an alloy, Pb 63 per cent., Sn 31 per cent., Cu 5 per cent., in which three constituents can be seen. The long, rough crystals of a compound of copper and tin have crystallized out first of all; then the excess of lead has solidified as grains and dendrites, and last of all, the eutectic has solidified.

LEAD AND ANTIMONY.

The curve of fusibility is composed of two branches which cut at a sharp angle at the eutectic point, 13 per cent. Sb at 228° C. according to Roland-Gosselin,* and 247° C. according to Stead.† *Fig. 34* shows the curve.

Cooling Curves : Antimony-Lead.
Bismuth-Tin.

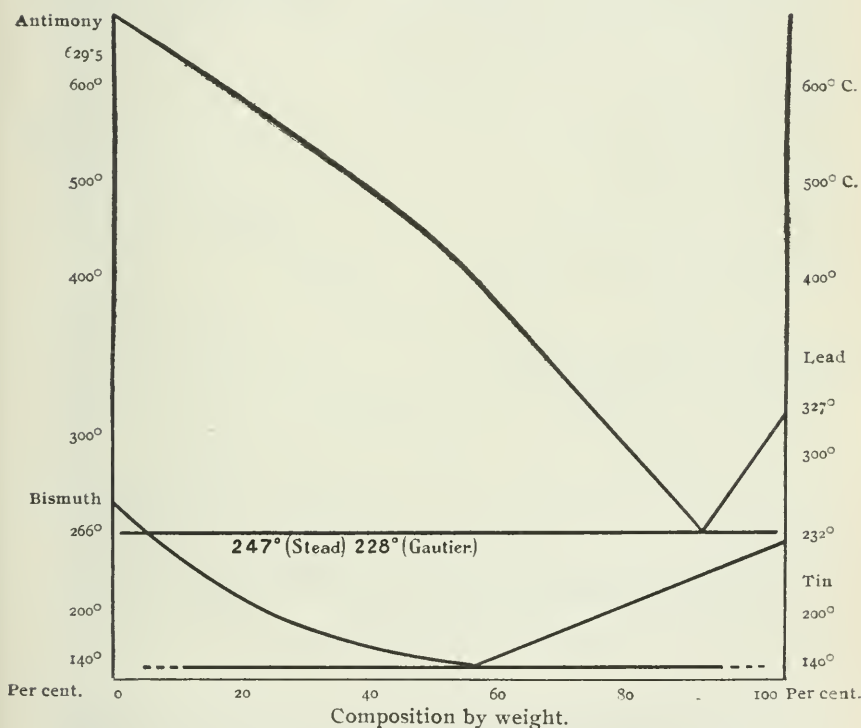


FIG. 34.

Alloys containing 0 to 13 per cent. Sb are extremely difficult to polish and etch properly. They are seen to consist of grains and then dendrites of lead in a matrix composed of alternate bright and dark laminæ, Sb and Pb. *Fig. 23* shows

*Gautier: *Bull. de la Soc. d'Encourage.*, 1896, Tome I, 5^e Série.

†*Journal Society Chem. Industry*, March and June, 1897.

the 10 per cent. Sb alloy, and the large skeleton crystals of lead are seen to have solidified in the eutectic. This eutectic corresponds to the formula Pb_4Sb , but this does not mean that a compound exists, but that the eutectic happens to have a percentage composition which corresponds to a formula. An exactly similar case is that of Levoll's alloy.

Above 13 per cent. Sb the slowly cooled alloys show a distinct layer of harder metal at the upper surface. This hard white layer increases in thickness as the total antimony in the alloy is increased, until at about 50 per cent. Sb the whole mass appears bright. Under the microscope these layers are seen to consist of more or less well-formed cubes imbedded in the eutectic. Stead has proved that these crystals crystallize out of a homogeneous mother-liquor, but by gravity float to the top. It is not a case of two liquids, as, for example, lead and zinc.

The crystals, on analysis, were found to contain at most 0.2 per cent. Pb, showing that the antimony crystallizes out in almost the pure state, or, in other words, that the concentration of the solid solution of lead in antimony is only 2 in 1,000, and that above 0.2 per cent. lead we get a eutectic. The specific gravity of these cubes of antimony is 6.5, whilst that of the eutectic is 10.5, which explains why the antimony is found on the top of the slowly cooled alloys. On analyzing the lower portion of any of the alloys from 13 to nearly 50 per cent. Sb, Stead found the composition to be 12.7 to 12.8 per cent. Sb, which gives us the exact eutectic point.

When these alloys are cast the cubes of antimony are comparatively small and are evenly distributed throughout the mass, thus allowing the alloys with the lower percentages of antimony to be used as bearing metals. *Fig. 24* shows the surface of an ingot containing 75 per cent. Sb, 25 per cent. Pb. The cubic growth of crystals of antimony resembles closely that of pure bismuth. As in the other illustrations of surface structures, the eutectic on cooling has shrunk and the antimony crystals stand out in relief. *Fig. 30* is very similar to the appearance of the bright layer

of antimony cubes in slowly cooled alloys containing from 15 to 30 per cent. of antimony.

TIN AND BISMUTH.

The curve consists of two branches meeting at $143^{\circ}\text{C}.$ * (Rudberg). The eutectic contains about 46 per cent. bismuth, 54 per cent. tin, and under high powers has a peculiar granular appearance. From tin to the eutectic we find

Silver-Lead.

Aluminium-Zinc.

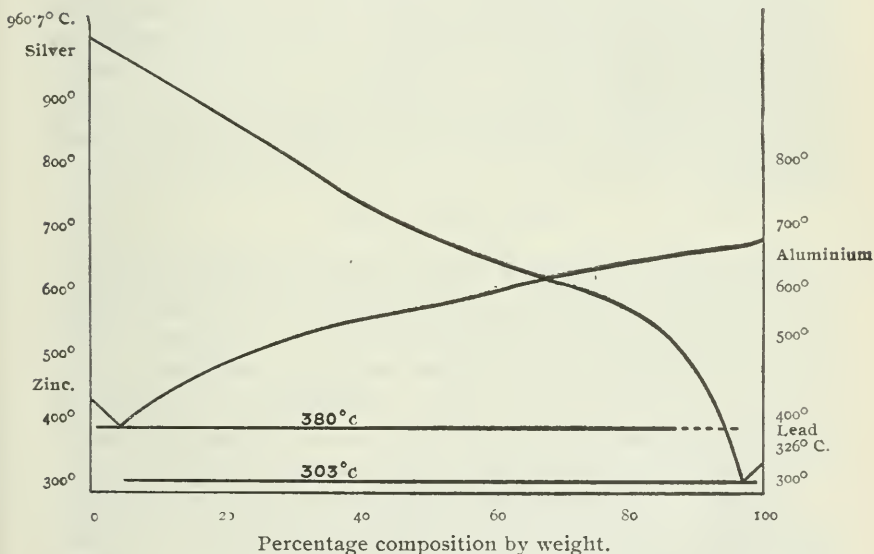


FIG. 35.

grains and then dendrites of tin crystallizing out in the eutectic. The alloys are similar in appearance to *Fig. 23*.

Above 46 per cent. Bi, irregular white crystals of bismuth make their appearance. In this case, however, their density is greater than that of the eutectic, and consequently they form and sink to the bottom when the alloy is slowly cooled.

* *Poggendorf's Annalen de Physik und Chemie*, xviii, 240. *Annales de Chimie et Physique*[2], xlviii, 353.

When cast they appear regularly throughout the mass. The cooling curve, *Fig. 34*, is based upon Dr. Gautier's figures in the "Fusibility of Metallic Alloys."

ZINC AND ALUMINIUM.

The two branches which compose the curve meet at about 5 per cent. Al. The eutectic melts at 380° C., some 39° below zinc, according to Heycock and Neville,* or 389° C., according to Roland-Gosselin. These alloys are extremely difficult to polish. They are best etched with nitric acid, towards the zinc end of the series, and with caustic soda at the aluminium end. The alloys consist of an excess of Al or of zinc in a eutectic consisting of laminæ of the two metals. *Fig. 25* shows the alloy 4 per cent. Al, 96 per cent. Zn. Grains of zinc appear in the typical eutectic.

SILVER AND LEAD.

The curve consists of two branches, meeting at 2.8 per cent. Ag, the eutectic point. This melts at 303° (Heycock and Neville), and the eutectic line extends from almost pure lead to about 96 per cent. Ag. Between 0 and 2.8 per cent. Ag we find lead crystallizing out first as rounded grains, then as dendrites in an increasing ground-mass consisting of alternate bright and dark laminæ.

Above 3 per cent. of Ag, bright white cubes make their appearance, together with well-formed octahedrons. These are silver, but contain some lead in solid solution. As the silver contents are increased, these octahedrons increase, tending to crystallize out along definite directions, and forming in this way large skeleton crystals of silver. *Fig. 26* shows this mode of growth in an alloy containing 10 per cent. Ag, 90 per cent. Pb. The skeleton crystals become more compact, the octahedrons forming them become less perfect, and there is a great amount of interference as the silver is increased. At 50 per cent. the silver forms a dense

* *Journal Chem. Soc.*, 1897, p. 383.

mesh throughout the alloy. This increases in thickness and the eutectic diminishes till at 96 per cent. Ag the whole mass appears to be made up of silver grains and dendrites. These alloys are best etched by prolonged action of acetic acid.

ANTIMONY AND COPPER.

The curve of fusibility, as determined by Le Chatelier, consists of three branches, which cross at the two eutectic points about 25 and 71 per cent. Cu. The summit of the middle branch occurs at about 60 per cent. Cu. According to Stansfield, the two eutectic points occur at 25 and about 69 per cent. Cu, and the summit at about 57 per cent. Cu. *Fig. 36* shows Dr. Stansfield's curve. The lower branches have as yet not been accounted for; but quenching the alloys involved, after complete solidification, but above the lower breaks, revealed new structures and this seems to point to a rearrangement in the solid similar to that in the copper-tin series.

With regard to the microstructure of the series, Charpy and Stead differ with respect to the alloys near the intermediate summit. Stead's work is summarized as follows:

100 to 75.8 per cent. Sb.—Antimony crystallizes in a eutectic of 24.2 per cent. Cu.

75.8 to 48.5 per cent. Sb.— SbCu_2 crystallizes in the eutectic, and increases with the copper, till at 51.5 per cent. Cu the whole mass is SbCu_2 , the purple compound.

48.5 to 38.5 per cent. Sb.—The purple compound SbCu_2 crystallizes imperfectly in what appears to be a second definite compound, SbCu_3 , which is white; the purple compound decreases and finally disappears when the Sb reaches 38.5 per cent., the whole mass being composed of a compound, white in fracture and when polished, but purple on etching with HCl.

Sb 38.5 to 31 per cent. Sb.—The structures of the alloys between 38.5 and 36 per cent. Sb are similar in appearance; thin veins envelop the grains, and from these veins needle-like processes penetrate into the grains for a very short distance. As the antimony is decreased below 36 to 31 per

cent., microliths of some compound appear in the center of the grains, and the veins enveloping the latter increase in thickness and in their copper contents. When 31 per cent. Sb is present, the microliths are present in increased quantity, and at this point it would appear that we have the second eutectic with a very complicated structure.

31 to 0 per cent. Sb.—As the copper is increased above 69 per cent. it at first falls out of the eutectic in detached iso-

Copper-Antimony.
Nickel-Tin.

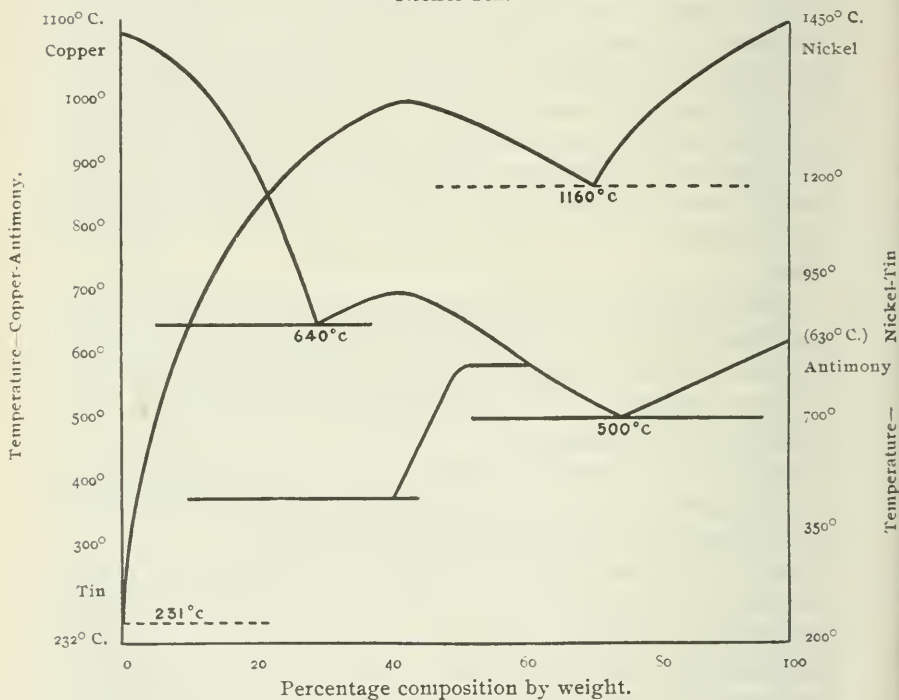


FIG. 36.

lated globulites. They are not pure copper, but contain Sb and arrange themselves in definite lines and angles. As the copper is increased, they form dendritic crystals. The microliths are absent and have probably been absorbed by the yellow-colored dendrites at the moment of solidification. The color of the dendrites passes from yellow to red as the

Sb is further reduced, and finally the last 0.1 or 0.2 per cent. are left behind at the borders of, but not separated from, the grains of copper, where it probably exists as antimonide of copper in solid solution. (Stead: *Journal Soc. Chem. Industry*, Dec. 31, 1898.)

Charpy's conclusions are as follows:

In the case of alloys containing less than 25 per cent. copper, pure crystals of antimony are separated when solidification begins, increasing gradually in size as the temperature decreases; the portion remaining liquid, therefore, gradually becomes richer in copper until the composition of the eutectic alloy is reached; it then solidifies at a constant temperature, through a simultaneous crystallization of Sb and SbCu_2 . In the case of alloys containing from 25 per cent. to 60 per cent. Cu, a similar phenomenon occurs, only it is the definite compound SbCu_2 which separates from the molten mass as soon as the freezing point is reached. When from 60 per cent. to 70 per cent. of copper is reached, the same compound is separated, but is in this case surrounded by a second eutectic alloy made up of copper and the compound SbCu_2 . Finally, when more than 70 per cent. of copper is present, a portion of the latter is first deposited when solidification sets in, until the portion remaining liquid has reached the composition of the second eutectic alloy (*Metallographist*, Vol. I, p. 100).

TIN AND NICKEL.

According to Charpy, the microstructure and the curve of fusibility seem to show that they have a constitution very similar to that of the copper-antimony alloys. The eutectic points occur at 2 per cent. and 70 per cent. Ni, whilst the summit of the intermediate curve occurs at about 43 per cent. Ni.

In *Fig. 36* the curve according to Gautier is shown.

ALUMINIUM AND ANTIMONY.

Gautier points out that the curve of fusibility of these alloys is remarkable, since nearly all its points correspond

to temperatures higher than those of the fusion of the two metals. He says that the curve indicates the formation of a compound SbAl , whose fusion-point is slightly lower than that of copper. Dr. Mathews' curve is shown in *Fig. 12* of his paper.

On a microscopic examination these alloys fall into two groups:

(1) 0 to 81.5 per cent. antimony, in which increasing amounts of the compound SbAl crystallize out, first as short rod-like crystals, then as more or less irregular bars and plates with much parallel growth. The groundmass is aluminium or aluminium containing some SbAl in solid solution. The groundmass disappears between 75 and 80 per cent. Sb and the alloy appears homogeneous.

(2) 81.5 to 100 per cent. antimony, in which we pass from the compound through a series of alloys composed of crystals of SbAl in an increasing groundmass till we reach pure antimony. The groundmass could not be resolved into two components, and probably consists of antimony containing some of the compound in solid solution.

The series is remarkable in many ways; for when the antimony reaches about 60 per cent. the alloys soon become rotten and rapidly disintegrate into a fine black powder. This is due to oxidation, according to Gautier; for if the alloy be weighed before and after disintegration it will be found to have gained in weight. If the fresh alloy be sealed up in vacuo, no change takes place. Again, when the antimony in the alloy is between 50 and 80 per cent. a great expansion takes place during solidification and part of the liquid residue is squeezed out and solidifies as a button on top of the alloy. That it takes place during the solidification of the crystals of SbAl is shown by the fact that the button contains a large percentage of the compound as well formed crystals. Lastly, it is seen that the curve consists of a rise from the aluminium end to the alloy containing 33 per cent. Sb . This is a summit, and the curve falls to 37 per cent. Sb , after which it rises again to 81.5 per cent. Sb . The reason for this has not yet been explained, for under the microscope the alloys between 33 and 40 per cent. Sb pre-

sent the same characteristics. A similar thing occurs in the alloys of tin and aluminium.

SILVER AND TIN.

The curve, like that of the silver-lead series, consists of two branches, the one curved, meeting at the eutectic point 3.5 per cent. Ag. The eutectic melts at 222°C . and extends from almost pure tin to 65 per cent. Ag, where it disappears.

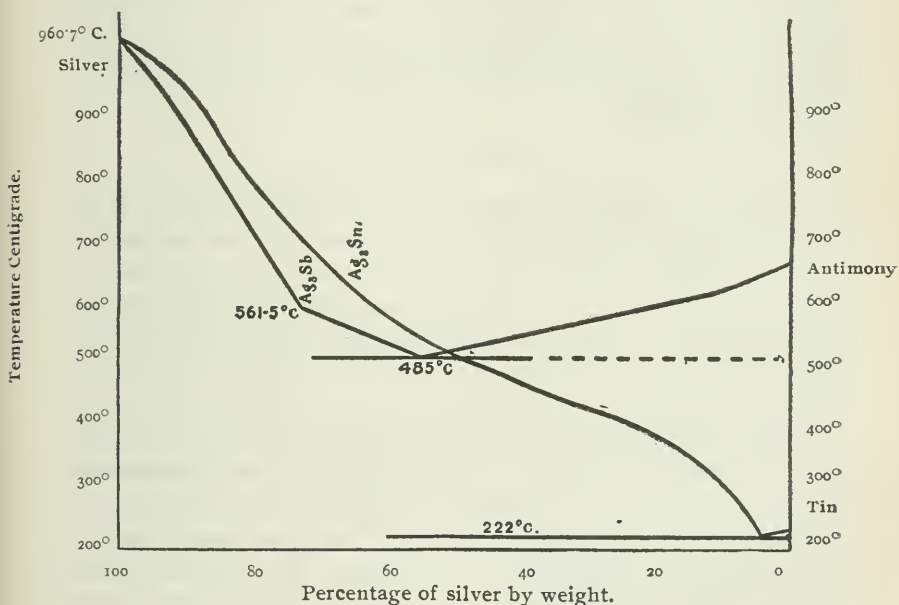
Silver-Tin.
Silver-Antimony.

FIG. 37.

According to Charpy, we have a compound Ag_2Sn at 65 per cent. Ag, and thus the series can be divided into—

(1) Alloys which are isomorphous mixtures of Ag and Ag_2Sn —between 100 and 65 per cent. Ag.

(2) Alloys of the compound Ag_2Sn and Sn, which are quite normal.

Between 0 and 3.5 per cent. Ag we find the excess of tin crystallizing out as grains in the eutectic. Above 3.5 per cent. Ag we find long, slender needles, probably of the com-

pound Ag_3Sn crystallizing out. The number and size of these hard, bright crystals increase with the total silver in the alloy. They assume curious tree-like shapes, finally becoming united and forming dendrites. At about 50 per cent. they occur as rounded grains in close contact. The eutectic diminishes, and at 65 per cent. Ag we find the alloy homogeneous. This alloy may either be a definite compound or it may be a solid solution of tin in silver. From this point onwards to pure silver the alloys are isomorphous with silver. *Fig. 29* shows an alloy of the first group containing 15 per cent. Ag, 85 per cent. Sn, and contains the curiously grouped crystals of the compound set in the eutectic. The curve, *Fig. 37*, is based on the freezing-point curve of Heycock and Neville.

ANTIMONY AND SILVER.

In *Fig. 37* we having the cooling curve based on the figures of Heycock and Neville. It is composed of two branches: the one from pure antimony to 55 per cent. Ag, the eutectic point, being normal: the other from silver, having a decided angle at 72 per cent. Ag, corresponding to the formula Ag_3Sb . The eutectic melts at 485°C ., whilst the 72 per cent. Ag alloy melts at 561.5°C .

According to Charpy, between 72 per cent. Ag and 0 per cent. Ag we have excess of either Ag_3Sb or Sb crystallizing out in the eutectic, in the same manner as all the alloys of Group I; between Ag_3Sb and pure silver we have a series of isomorphous mixtures of the definite compound with silver. It may be, however, that here we are dealing with a case similar to the antimony end of SbSn series, and that we have dendrites of silver crystallizing out in the compound Ag_3Sb . This point will be settled when a complete cooling curve has been taken of this end of the series.

TIN AND ANTIMONY.

Between 0 and 7.5 per cent. of antimony the alloys crystallize out in the same forms as pure tin; in other words, the tin will retain some 7.5 per cent. of Sb in solid solution, probably in the form of the compound SbSn . When the

antimony is increased above 7·5 per cent., some very hard, bright cubes are found at the surface of the alloy when slowly cooled, but when cast the cubes are found scattered throughout the alloy. The bright layer of cubes increases in thickness with the antimony in the alloy, till at about 30 per cent. Sb it reaches the base of the alloy, and the groundmass is seen occupying the interstitial spaces. At about 40 per cent. the form of the cubes begins to change, and at 45 per cent. Sb the alloy consists of squat, thick bars or plates crossing at all angles, the spaces between being still occupied by a groundmass similar to that found in the lower percentage alloys. At about 52 per cent. Sb, a new constituent, probably antimony, is found making up the core of the bars or plates, but there still remain traces of the groundmass, which finally disappears at about 55 per cent. Sb. The cores of the bars continue to increase and develop into the usual crystals of antimony and, at about 95 per cent. Sb, become continuous. In the joints between them traces of a matrix are seen, which finally disappear as we approach pure antimony.

Fig. 30 shows a vertical section through the center of a slowly cooled alloy containing 20 per cent. Sb, 80 per cent. Sn. The bright cubes are seen set in the softer matrix. Stead found that the common freezing point of this matrix between 7·5 per cent. and 50 per cent. Sb to be $256^{\circ}\text{C}.$, which is remarkable since it is higher than that of pure tin by $25^{\circ}\text{C}.$ On analyzing the cubes isolated from a 25 per cent. Sb alloy, he found their composition to be approximately SbSn. He says that a homogeneous mass corresponding to SbSn cannot be obtained, for on melting the metals in that proportion the resulting alloy consisted of the peculiar plates and the dark matrix; that the crystals up to 30 per cent. Sb are SbSn, but in the neighborhood of 40 per cent. Sb the forms begin to change and the contents of antimony increase. This is contrary to Behrens,* who isolated from the 10 per cent. alloy cubes with the formula SbSn_2 , and from the 64 per cent. Sb alloy a residue of the formula SbSn.

**Metallographist*, Vol. III, page 11.

According to Stead, the specific gravity of the cubes is 6.96, which is lighter than that of the groundmass, and thus they float to the top of the slowly cooled alloys, just as the antimony in the lead-antimony alloys. *Fig. 31* shows the surface structure of the cast 25 per cent. Sb alloy, in which the cubes are quite distinct. In *Fig. 32* we have the 70 per cent. Sb alloy, showing the crystals of antimony set in a matrix, which is probably SbSn , containing much antimony in solid solution. Stead puts forward the alternate view that Sb and SbSn may form isomorphous compounds with each other, and when the antimony reaches a certain point it crystallizes out in a separate state.

The alloys of tin and phosphorus and of tin and arsenic probably belong to the same group as tin and antimony.

TIN AND PHOSPHORUS. TIN AND ARSENIC.*

When phosphorus is added to tin, a hard constituent, consisting of brilliant white plates, similar to graphite, is formed. Stead has studied the series from 0.04 per cent. to 5 per cent. phosphorus. The structure of these alloys can be developed by polishing alone, for the phosphide formed stands out in relief from the soft matrix of tin between. On etching with dilute acid this groundmass of tin (probably containing some phosphorus in solid solution, for its melting point is 4°C . above that of pure tin), turns black, and the hard white crystals of phosphide stand out in strong contrast. When analyzed the bright white plates proved to have the composition Sn_3P_2 . When the alloy is slowly cooled the phosphide invariably commences to grow at the outer portion of the alloy and travels in straight lines toward the center. The plates have a decidedly hexagonal form. *Fig. 28* shows an alloy containing 2 per cent. phosphorus; it has been cast, and so the phosphide appears as comparatively small thin plates throughout the groundmass.

When arsenic is added to tin, thick rough plates are formed, having the composition Sn_3As_2 . The groundmass consists of tin, probably containing some arsenic in solid

* Stead: *Journal Society Chemical Industry*, March, 1897.

solution, because, as in the case of phosphor-tin, the melting point has been raised some 4° C. Stead was able to introduce as much as 43 per cent. As into tin. *Fig. 27* shows a slowly cooled alloy, in which the thick rough plates of arsenide run in all directions, with a tendency towards parallel growth. The alloy contains 20 per cent. As.

COPPER AND TIN.

The microstructure of the copper-tin alloys has been studied by Behrens, Charpy, Stead, Heycock and Neville. The earlier explanations were based on Le Chatelier's curve of fusibility, which consists of three branches forming by their intersections two points corresponding to alloys with 3 and 72 per cent. of copper. These two points correspond to the two eutectic alloys of the series. The existence of the compound SnCu_3 (61.7 per cent. Cu) has been proved, for at this point we find discontinuities in the variations of many properties, such as the electromotive force of dissolution (Laurie); the electric conductivity (Mathiessen); the specific gravity (Riche). Hence it was thought that the series consisted of two simple sets of alloys, viz.: the alloys of copper and SnCu_3 and the alloys of SnCu_3 and tin, and was similar in structural variation to the alloys of copper and antimony.

This view of the constitution of this series of alloys does not explain the complete freezing-point curve published in the fourth report of the Alloys Research Committee, Institution of Mechanical Engineers, shown in *Fig. 38*. It was not until recently that an explanation of the branches *b*, *d* and *e* was offered.

0 to 1 per cent. Copper.—When 1 per cent. of copper is present the first eutectic alloy is obtained; that is, the one with the lowest freezing point. Between pure tin on the one hand and this alloy containing 1 per cent. Cu on the other, tin is found crystallizing, first in grains, then in dendrites in the eutectic. The cooling curves of all the intermediate alloys show two breaks.

1 to 8 per cent. Copper.—When the percentage of copper is increased above that of the eutectic alloy, thin, bright, hol-

low crystals are seen. In section they are horseshoe-shaped, and at first occur isolated; then they tend to form groups which appear in section as three- and six-rayed stars. Their composition varies also, increasing in copper from 34 to 44 per cent.

8 to 40 per cent. Copper.—A third constituent is seen when the copper exceeds 8 per cent. We have the eutectic or groundmass enclosing the bright porphyritic crystals characteristic of the 1 to 8 per cent. alloys, but these bright crystals are seen in places to have grown on and around a different kind of crystal. It is not a case of one crystal varying in composition from the center to the faces, for a sharp line of junction can be seen between the two constituents. On oxidation this new constituent becomes very dark, and is easily distinguished from the other two constituents of the alloy. As the percentage of copper is increased, the more easily oxidized crystals increase in number and size; whereas the bright crystals begin to decrease together with the eutectic. It would, therefore, appear that in alloys containing more than 8 per cent. of copper, the first constituent to crystallize out is the central, easily oxidized crystals. This causes the first rest in the cooling curve *d e*. Then the bright crystals solidify, causing the second halt on the horizontal branch *e' e*. Lastly the eutectic solidifies and the third halt is reached on branch *f' f*. As branch *e' e* is horizontal, it would seem that the bright crystals have a definite composition when above 8 per cent. Cu is present in the alloy, but when branch *e' e* joins the outer curve at *e* and falls to *f*, these crystals no longer have a definite composition, but their percentage of copper falls with their temperature of solidification from Sn_2Cu_3 to SnCu .

The upper curve in *Fig. 38* shows the relation between the percentage of copper in the alloy to the percentage of copper in the crystals which have been isolated. A break occurs at 8 per cent. copper, at the introduction of the third constituent to the alloys. These results agree very closely with those of Stead.*

* *Journal Society of Chemical Industry*, June, 1897.

As the copper approaches 40 per cent., the central plate-like crystals are grouped together in parallel bunches, until at 40 per cent. Cu they are very thick and cover more than half the field. In the eutectic between them the small, bright, hollow crystals are seen.

41 to 61.7 per cent. Copper.—The difference between the alloy containing 40 per cent. and that containing 41 per

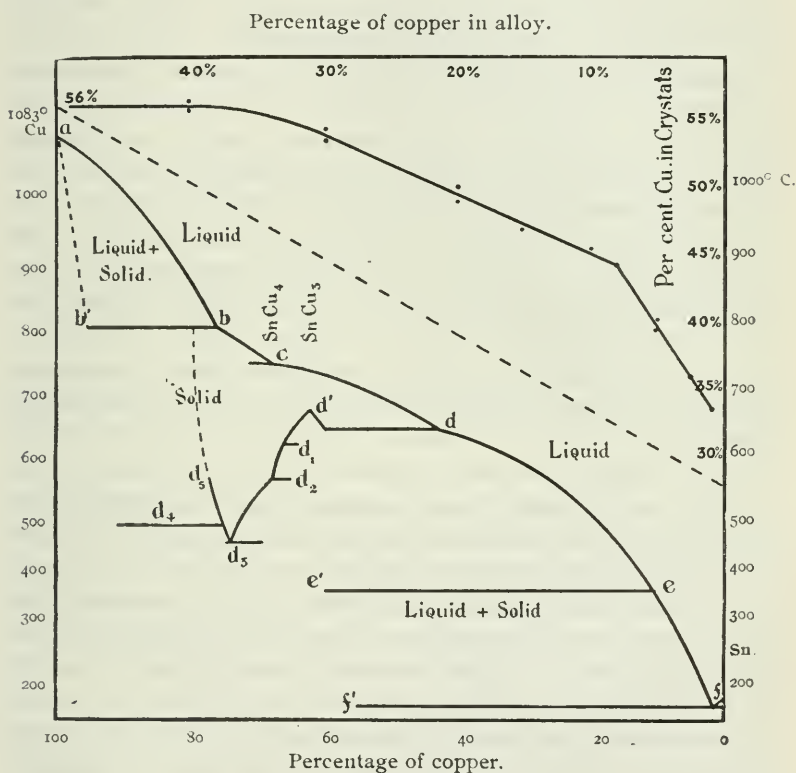


FIG. 38.

cent. Cu is very marked. The crystals in the latter are small and lath-shaped, arranged more or less in groups and are separated from each other by eutectic. They are composite as before, but the white constituent surrounds the dark as an envelope of uniform thickness, not as a rough incrustation. No single prismatic crystals of the white constituent have been seen in the eutectic. With each

addition of copper the groups of crystals become more and more compact and the amount of eutectic diminishes until at 56 per cent. Cu it disappears altogether.* Therefore branch $f f'$ of cooling curve ends at 56 per cent.

The bright constituent of the crystals grows smaller and smaller; at 56 per cent. Cu it takes the place of the eutectic and forms the groundmass, whilst at about 61 per cent. Cu it disappears and we have a homogeneous mass of SnCu_3 . Hence branch $e e'$ ends at 60 per cent. at e' .

Seeing that these alloys up to 56 per cent. Cu show four breaks in their cooling curves, one would naturally expect to find four different constituents in each. Only three, however, can be distinguished. Quenching below the first and second breaks gives a difference in structure only. As in the alloys containing 61.7 per cent. Cu and onwards, branch d of the freezing-point curve corresponds to a rearrangement in the solid, and as the difference between the 40 per cent. alloy and those of a higher copper contents is one of structure only, we may assume that the second retardation in the cooling curve dd' is one of rearrangement also.

61.7 to 68.2 per cent. Copper. SnCu_3 to SnCu_4 .—The changes which take place between these two points can only be observed when the alloys are very slowly cooled. The alloys set as a whole at the first break on $c d$, and tend to rearrange themselves subsequently in the solid. Near SnCu_3 we see the dark grains of this compound surrounded by an envelope of a bright material, probably SnCu_4 , whose formation is indicated by d_1 in the cooling curves. Each addition of copper brings in more and more of the bright constituent. Above 65 per cent. Cu we find, in places, a structure like that of a eutectic which accounts for the horizontal branch d_2 of the curve. At 68.2 per cent. Cu we have a homogeneous alloy, very brittle, taking a beautiful polish, and this very probably is a definite compound, SnCu_4 . When the alloys of this group are quenched at definite temperatures, very many curious and beautiful

* Stead: *J. S. C. I.*, June, 1897.

structures are met with. For example, if the 66 per cent. Cu alloy be quenched below the first break, say at $720^{\circ}\text{C}.$, then a clear cell-like structure is seen. If it is quenched between the first and second break, say at $650^{\circ}\text{C}.$, then the structure consists of a network of parallel straight lines, alternately light and dark. Each large area has two or more sets of lines, which are differently orientated for different areas. It may be called the "Schiller" structure of these alloys. If the alloy be quenched below the second break, but above d_2 , say at $600^{\circ}\text{C}.$, the structure is almost the same as that met with in the slowly cooled alloy, except that no sign of any eutectic can be seen. If the 68.2 per cent. alloy be quenched just after the first break, its structure is that of dark rounded grains passing imperceptibly into a light-colored groundmass, clearly showing that the alloy is in a metamorphic state. Thus it seems quite certain that in this group the alloys rearrange themselves in the solid.

68.2 to 75 per cent. Copper.—In this group we pass from the homogeneous SnCu_4 , consisting of irregular and elongated grains, to the so-called second eutectic at 74 to 75 per cent. Cu. Between these two alloys we find the compound SnCu_4 crystallizing in the eutectic. Near 68.2 per cent. Cu the alloys are composed of polygonal grains, with boundaries of bright SnCu_4 . Their central parts are composed of dendrites and rosettes of SnCu_4 set in the eutectic. Near 74 per cent. Cu the alloys are composed of attenuated rosettes and grains of SnCu_4 set in a comparatively large amount of eutectic. Thus the upper part of branch d , between d_2 and d_3 , marks the point at which these alloys rearranged themselves into grains isomorphous with SnCu_4 , whilst the horizontal branch d_3 marks the formation of the eutectic, both changes having taken place in the solid. At c there occurs a small horizontal branch, the meaning of which is not quite certain. A microsection of an alloy quenched between this and the outer curve shows dark rounded grains set in a light groundmass. Heycock and Neville say that the outer curve $b\ c$ indicates the formation of skeletons rich in copper; but when the alloys are quenched below the horizontal branch c , then

we have uniform solid solutions. It is to be noted that on the surfaces of alloys containing 70 per cent. or more copper, a network of dendrites or skeleton crystals resembling those on the surface of a pure metal is to be seen. It was soon noticed that the internal structure of the alloys from 70 to 75 per cent. Cu showed no trace of these dendrites, and so the surfaces of several were rubbed down, polished and etched so as to lay bare their internal structure. In each case it was the same as that of the center of the alloy, which shows that these dendrites have split up and rearranged themselves after solidification, and all that remains of them is this surface structure.

75 to 100 per cent. Copper.—Above 75 per cent. Cu two new constituents make their appearance and the alloy assumes a yellow tint and begins to lose its brittleness. In section we find yellow grains surrounded by a bright white border, set in the second eutectic, in which small white grains also occur. Now this eutectic at 76 per cent. Cu is much larger in character than the 74 per cent. alloy, and this may account for the fact that the eutectic break rises some 30° C. as it passes from 74 to 75 per cent. Cu.

As the total copper is increased the yellow grains increase, forming dendrites and skeleton crystals, the white borders and grains merge together, and the eutectic decreases till at about 90 per cent. Cu it disappears. The yellow grains of copper become darker and darker (contain less and less tin in solid solution) till they reach copper color. The light borders diminish and disappear about 95 per cent., leaving copper dendrites alone. These dendrites vary in composition from center to outside, and so the center etches a darker color. These dendrites darken with increase of copper till about 100 per cent. is reached, when we have the characteristic structure and color of pure copper.

Quenching these alloys at different temperatures proves that copper grains and dendrites begin to crystallize out as soon as an alloy has reached the temperature of the outer curve *ab*; that these continue to grow till the temperature falls to *b'b*, when the whole mass becomes solid; at this

point we have crystals of copper in a homogeneous groundmass. Above the curve $a b$ the alloy is liquid, below $b' b$ the alloy is solid, whilst between $a b$ and $b' b$ we have a mixture of solid and liquid. The composition of the copper dendrites crystallizing out of any particular alloy would be given by the composition line $a b'$.

Below $b' b$ the groundmass consists of a solid solution much richer in tin than the grains of copper in it. It is probable that these grains of copper continue to grow in the solid until at about 500° C. the groundmass has arrived at the composition 75 per cent. Cu, when it splits up into a eutectic composed of laminæ of SnCu_4 and Cu, containing a considerable amount of Sn in solid solution. This change in the solid is marked by branch d_4 .

The meaning of branch d_5 is obscure. It may indicate the formation of the bright white grains seen in the 76 and 77 per cent. alloys.

In their recent papers before the Royal Society of London and elsewhere, Heycock and Neville* have clearly proved that the great changes which take place when a bronze reaches the temperature of the curve $d' . . . d_4$ are entirely in the solid. They go further than this by determining the various substances or phases which exist in the various alloys, either chilled or slowly cooled. Their modification of the cooling-curve diagram by the addition of a curve indicating the position of the *end* of solidification of each alloy and their explanation of this new diagram, go far in clearing up many of the numerous difficulties met with in the alloys of copper and tin.

ALUMINUM AS A SUBSTITUTE FOR COPPER.

The possible substitution of aluminum for copper in electrical work is a question which has been discussed from time to time in the press; frequently, we regret to say, by writers who apparently know very little about the facts. It has also been referred to by electricians, some of whom have been able to speak from actual experience. From the expert testimony it appears that

* *Proceedings Royal Society of London*, Vol. 68. *British Association*, Glasgow Meeting, 1901, Chem. Section.

aluminum can be and has been used for conducting purposes in power plants and for the transmission of power from such plants. The most notable employments of the metal for the former purpose have been in some of the recent installations at Niagara and in some California plants; for the latter at Snoqualmie Falls in Washington, and the Blue Lakes power plant in California. Notes of these uses of the metal have appeared in our columns from time to time; and its use at Blue Lakes was fully treated by Dr. F. A. C. Perrine in a paper read before the Institute of Electrical Engineers.

The testimony of experts is that aluminum has given good results where it has been used; and that its lesser conductivity, as compared with copper, and its lower tensile strength, requiring the use of bars and wires of larger section, are so balanced by the low specific gravity of the metal that in the matter of cost aluminum at its present prices is about equal to copper at 16 to 17 cents a pound—that is, at present prices. For transmission wires there still seems to be some doubt whether, in a northern climate, aluminum wires will stand the stresses of snow, ice and high winds as well as copper. In a milder climate this consideration might be disregarded.

It may be assumed, therefore, that it would be possible to substitute aluminum for copper in electrical work to a considerable extent—provided the metal can be had in sufficient quantities for the purpose. That is, after all, the most important question. For all immediate purposes the question seems to be answered by the fact that in 1900 the total production of aluminum in the world was 5,570 metric tons, of which the United States furnished 2,053 tons; while that of copper was 492,625 metric tons, of which 272,536 tons were supplied by this country—that is, the total output of aluminum last year was only 1.1 per cent. of that of copper. Until these figures are greatly changed, the competition of aluminum is not likely to affect the copper market.

The price of aluminum at present is—as stated above—about on a par with that of copper, allowance being made for the respective weights. The aluminum quotations, however, have not been regulated by those of copper, but have been based, as we understand, upon the cost of production. They have shown little change during the past year. There is no competition tending to lower them; but on the other hand it is to the interest of the producers to keep them as low as possible in order to dispose of their output.

The main point to be considered, therefore, is to what extent the production can be increased. There is a general indefinite idea prevalent that as alumina is so abundant and so universal in its occurrence, it ought to be possible to extend the extraction of its metallic base indefinitely. That this is not the case is shown sufficiently—without going into details—by the fact that present production is so small, although the best metallurgical skill has been for years concentrated on the problem of separating the metal.

We do not mean to say that cheaper and more expeditious processes of furnishing aluminum may not be discovered hereafter. That is a problem which may be worked out by some investigator to the great benefit of the world—and himself. It has not been done yet, and considering present conditions, as we must, we are unable to see any opening for the substitution of aluminum for copper—or for any other metal—on a commercially important scale.—*Eng. and Mining Jour.*

Mining and Metallurgical Section.

[*Joint meeting of the Section and the American Institute of Mining Engineers, held Wednesday, May 14, 1902, at the Manufacturers' Club, Philadelphia.*]

The Beaumont Oil Field, with Notes on Other Oil Fields of the Texas Region.

BY ROBERT T. HILL, Washington, D. C.

(Continued from p. 94.)

OIL-FIELDS OF THE TEXAS REGION.*

While the phenomena of the Beaumont field have attracted great attention, many are not aware of the fact that in the State of Texas there are several other oil-fields (productive or prospective) entirely distinct from the Beaumont field, and from one another, in geological and geographical conditions. One of these has been productive for many years, while the others may some day give profitable returns.

One of these fields is already a large producer of a high-grade illuminating oil, supplying nearly 1,000,000 barrels per year of oil as good as that of the Washington County (Pa.) field. There are also many localities where bitumen occurs as asphaltum.

The typical oil and asphaltum horizons of Texas are as follows :

The Beaumont.

Nacogdoches.

Corsicana-San Antonio (Uvalde asphalt).

The St. Jo (asphalt).

The Brownwood-Henrietta.

The Trans-Pecos.

The Buckhorn (asphalt).

* See also "Bulletin U. S. Geological Survey," by George I. Adams, Washington, 1901.

Of these, one asphalt-field is found in the Ordovician rocks; two oil-fields (the Brownwood-Henrietta and the Trans-Pecos) in the older (Carboniferous) rocks of the Coastal Plain; and the others in the Cretaceous and Tertiary. I shall briefly describe each of these fields in ascending stratigraphic order, which also corresponds to their relative importance.

In the Southern Indian Territory there are, in Ordovician and Carboniferous formations, many asphalt springs and bituminous rocks which show the presence of a great amount of bituminous material. These asphaltic deposits have been recently described in detail by the United States Geological Survey in a paper entitled "The Asphalt and Bituminous Rock Deposits of the United States," by George H. Eldridge.*

THE PECOS OIL-FIELD.

In Reeves, Pecos and El Paso Counties, Texas, and in Eddy, Otero and Chaves Counties, of southeastern New Mexico, there is a prospective field in which many "seeps" have been found, and oil in small quantities has been struck in wells. This region lies immediately west of the Pecos River, and extends north of the Southern Pacific Railroad, far into Southern New Mexico, and adjacent to the eastern slope of the Guadalupe Mountain uplift.

The geological series seems to have, primarily, a great thickness of indurated Carboniferous limestone at the base; then a series of sands and bituminous shales; then another vast thickness of Upper Carboniferous and Permian limestones; then shales and clays of Permian or Triassic Age; then the basement-sands and limestones of the Comanche Cretaceous; the whole being largely obscured toward the Pecos Valley by large quantities of wash and desert debris. The geological structure consists of a long monoclinial uplift dipping, from the western crest of the Guadalupe-Sacramento Range and the Comanche Range, eastward

* See "Twenty-second Annual Report of the Director of the U. S. Geological Survey," 1900-1901, Part I.

toward the Pecos River. This monocline is waved by numerous secondary anticlines and synclines, and steep faults to the west. By reason of the ease with which the many low secondary anticlines and synclines can be made out, this structure is apparently more propitious for the location and extraction of oil than that of any other Texas field.

Most of this area lies upon the eastern slope of the monoclinical mountains of the Comanche and Guadalupe-Sacramento Range. A few oil-indications have been found farther west, in the Salt Basin flat.

Within the area mentioned, oil, asphaltum and sulphur have been encountered at numerous places in wells or springs, and upon the surface; and while the region has not yet been minutely studied, there is every indication that by scientific study and exploration it can be developed into an oil-field. Unfortunately, the only drawback, up to date, is the fact that the oil thus far encountered is of a very inferior quality, containing, as shown by Professor Phillips,* a residue of 45 per cent. of asphaltic material, and only about 25 per cent. of all grades of illuminants.

THE HENRIETTA-BROWNWOOD FIELD.

In this field, coincident with the Carboniferous outcrops in Northern Central Texas and the Southern Indian Territory, numerous finds of oil have been made in small quantities, notably at Henrietta, Clay County, and in Brown and Coleman Counties.

These Carboniferous formations are of great thickness (over 7,000 feet in Texas), and apparently contain many oil-bearing horizons. They also furnish some of the maltha springs of the Chickasaw Nation in the Indian Territory, and the oil and gas of the Northern Indian Territory and Kansas. No oil in commercial quantities has as yet been found in this field; but the quality of that hitherto found has been good. Exploitation is proceeding rapidly.

* "Bulletins Nos. 1 and 2 of the Mineral Survey of Texas," Austin, Tex., 1901-1902.

BITUMINOUS HORIZONS IN THE BASE OF THE CRETACEOUS.

The basement-beds of the Comanche series of Texas and the Southern Indian Territory are bituminous in several places, notably between Emmet and Caddo, I. T.; at Matubby Springs, about 5 miles northwest of Caddo; at Oakland, 16 miles southwest of Emmet; and at Marietta.* At these localities the basement-sand of the Cretaceous is impregnated horizontally. Crossing Red River to the southward, rich bituminous impregnations are similarly found in the basement-sands near St. Jo, Montague County. Some 200 miles further south, in Burnet County, asphalt is again found in the vicinity of the town of Burnet, impregnating small breccia at the base of the Cretaceous.

There are several minor beds of shale and clay in the Cretaceous, which have furnished traces of petroleum and asphalt. A mile or two west of Austin, a little petroleum was found in the Del Rio clays. Traces of petroleum have frequently been found in the Eagle Ford shales, notably at Watter's Station, north of Austin, and in the northwest in Grayson County, on Red River.

THE CORSICANA OIL-FIELD.

Since 1891, illuminating oil has been produced in the vicinity of Corsicana, where the Standard Oil Company has had a refinery. In 1900, the production of this district was 829,560 barrels. The oil is of fine quality, analogous to that of Washington County (Pa.) field, and has a paraffine base. The wells are not gushers, but are pumped from depths averaging about 1,100 feet.

Unlike the oil of the Beaumont field, that of Corsicana is distinctly a sheet-oil; that is, occurs in a definite geological stratum, namely, a horizon in the bituminous sandy clay shales of the Navarro beds, of the upper portion of the Gulf series of the Cretaceous. The geological position is closely near that of the Florence and Boulder oil-fields of Colorado.

An interesting feature of the Corsicana field is the fact that the Upper Cretaceous strata from which the oils are derived contain at least two distinct oil-bearing horizons:

* See paper by Eldridge, previously cited.

the uppermost has an asphaltum base, while the lower is of a paraffine nature. The upper bed is encountered at Powell, about 20 miles east of Corsicana; and I estimate that it is from 500 to 1,000 feet above the lower, which supplies the Corsicana wells.

These strata extend, with very slight variation, completely across Texas, from near Boston on Red River to near Eagle Pass on the Rio Grande, in a curved line 750 miles long. An oil-asphaltum has been found in them at several places, notably, a trace in the well at Bremond; a trace in Eastern Travis County; near Elgin, near Lytton in Caldwell County; a few miles east of San Antonio; and on the Sabinal in Medina County. The asphaltum-beds of Uvalde and Kinney Counties are derived from practically the same strata. It is the writer's opinion that when the continuity of this bituminous formation across the State has been fully appreciated and exploited in a scientific manner, many productive spots, similar to the Corsicana basis, may be found

THE NACOGDOCHES OIL-FIELD.

A number of years ago, oil was struck at shallow depths in wells in Southern Nacogdoches County, about 100 miles west of north from Beaumont. According to the studies of various geologists, the horizon of this oil-field is near the top of the Claiborne Eocene of the Tertiary.

A fine-grained quartz-sand, saturated with oil, which on the outcrop is a semi-asphalt, is apparently the source of the oil. It lies immediately below a green horizon, the outcrop of which is easily traceable by its blood-red soil, a product of the oxidation of glauconite.

Since the discovery of oil at Beaumont, renewed interest has been awakened in Nacogdoches, and several wells are being drilled.

At many other localities throughout the outcrop of the Eocene Tertiary of Texas, traces of oil have been found. Much interest is now shown in the vicinity of Sutherland Springs, Wilson County. A good oil is also reported 14 miles south of Campbellton, near the junction of Atascosa, McMullen and Live Oak Counties.

THE BEAUMONT OIL-FIELD.

This name the writer prefers to use for the oil-producing district within the area of the Coast Prairie of the Texas, Louisiana and Mexican Region.

Discovery.—Before the first white man came, it was known that oil existed in small quantities in Western Louisiana and Texas, within 100 miles, more or less, of the present site of Beaumont. It was a matter of rumor for many years that oil floated upon the sea just west of Port Sabine. Petroleum springs existed at several places, notably, Lake Charles, La. It had also been encountered in the well-borings in Western Louisiana, East of Beaumont. As early as 1862, unprofitable attempts at drilling had been made at Sour Lake. Even at Beaumont, similar attempts failed. Until 1901, no man had obtained the oil in commercial quantities.

The finding of oil at Beaumont was not an accident, but, like all other great discoveries, the dramatic culmination of long and extensive research and many experiments, each of which was an important factor in the final result. Capt. A. F. Lucas, to whom the glory of the crowning achievement is fairly due, has been, since 1892, carefully studying the geology of the Coastal Plain of Western Louisiana and Eastern Texas, with the view of developing its salt, sulphur and petroleum. With the aid of every recorded observation which he could obtain, supplemented by his own experience and reasoning, he concluded that the structure and stratigraphy of Beaumont gave the best prospect of oil. Previous failures at this place were, in his judgment, due to mechanical difficulties, which could be overcome—an opinion which he fully confirmed by his work.

Captain Lucas, a native of Austria, and graduate of the Polytechnic School of Gratz and of the Imperial Austrian Naval School, had been for some ten years actively engaged in this country as a mining engineer, especially in the development and operation of the salt mines of Louisiana.*

In connection with this work he found, in one or two

* See his paper on "Rock-Salt in Louisiana," *Trans. A.I.M.E.*, xxix, 462.

places, indications of oil, and also of sulphur (of the existence of which, in that region, the famous Calcasieu deposit is a proof). Conceiving the plan of a systematic exploration for oil, he finally chose Beaumont, Tex., as the scene of operations. His first well, begun in 1899, was 575 feet deep in March, 1900, and showed a trace of oil at the bottom, when the casing broke, and the well had to be abandoned. Not daunted, he commenced in October, 1900, another well beside the old one. The public will never realize the obstacles and difficulties which had to be overcome. One of Captain Lucas's greatest technical achievements was the putting of a drill hole through 1,100 feet of clay and quicksand. The methods and contrivances used by him made possible the other wells which have followed. This second well, which "came in" January 19, 1901, was the famous "Lucas Gusher."

Economic Conditions of the Beaumont Oil-Field.—The Beaumont oil, when first discovered, was found to be of a different quality from that of any other field, and many doubts arose as to its value and uses. Having a heavy base of asphaltum, and being thoroughly impregnated with sulphur, it was supposed to have no value as an illuminant, and many believed that the excess of sulphur would so corrode boilers that it could not be used as a fuel. This sulphur was so apparent that on occasions, as on March 4, 1902, it filled the atmosphere, leaving a coating of sulphur on many of the houses in Beaumont, some 3 miles from the oil-field.

The chemical analysis of the oil is as follows:

COMPOSITION OF BEAUMONT OIL. FROM CHEMICAL ANALYSES BY PROF.
F. C. THIELE.

I.

	Per Cent.
Kerosene	36'00
Light lubricating oil	21'05
Medium lubricating oil	21'05
Heavy lubricating oil	10'52
Asphalt	6'34
Loss and gases, including sulphur	5'04

100'00

Color of crude oil : brown, opaque.

Sp. Grav., 0'9206, equal 22° B. at 62'57° F.

II.

Naphtha	6'45
Kerosene	35'00
Lubricating oil	43'90
Residue and gases	14'65

 100'00

Test of obtained kerosene :

Color	Prime white.
Sp. Gr.	0.872 equal 30° B. at 65.5° F.
Flash-point	120° F.
Fire-test	150° F.

It was soon realized that, if fit for no other uses, this was an excellent fuel. After a year of experiment, it is now generally conceded that the oil has many excellent qualities, and that, after refining for the kerosenes, the remainder is as good a fuel and gas-making material as can be desired. Upon the basis of elaborate refinery, chemical and fuel-tests, made on large quantities, the following facts may be stated as established: (1) The Beaumont oil has a low flash-point of 120° F., which renders it an unsafe, or at least undesirable, cargo in tank-ships; (2) refined by first distillation, it produces 30 per cent. of export illuminating-oil, leaving a residuum of good fuel-oil, which can be transported with perfect safety; (3) the sulphur can be extracted if necessary, but when left in the oil has no injurious effect whatever upon the boilers, while it adds to the fuel value; (4) as a fuel, three barrels of this oil can be delivered by rail in any city in Texas at a price of \$2.70, the price of bituminous coal being \$5, and that of anthracite coal \$10 per ton. The oil may be laid down in New York, Philadelphia or Boston at 75 cents a barrel.

The flash-point of the crude oil is too low for marine insurance, but this defect can be obviated by a profitable preliminary refining, whereby the naphtha and kerosene are extracted, and the flash-point is raised to a standard for safe shipment.

Immediately after the discovery at Spindle Top every acre within 50 miles was leased, and wells were started everywhere. Since, then, it took from three to six months to put down one of these costly wells, some time was

required to show by experiment that all the oil in the immediate vicinity of Beaumont was confined to Spindle Top Hill, within an area of less than 300 acres.*

This was at first seriously discouraging. Many thought that if the oil was confined to this one small locality it would soon be exhausted, and the business would be at an end. Prudent operators at Spindle Top did not feel justified in making longtime contracts; and railways and factories, with the risk of an exhausted supply before them, naturally hesitated to make the expensive changes required for the use of this fuel.

The "coming in" of Jennings, Sour Lake and Saratoga removed the fear of inadequate supply; and no one now apprehends an early cessation of production, even if Spindle Top should soon be exhausted, which has not been proved probable.

When the Beaumont well was discovered, the writer, aware that similar conditions existed over a wide area, ventured the following prophecy :

"It is entirely within the limit of probability that oil will be found at many places throughout the Coastal Prairie, especially in its southern extension toward the Rio Grande and in the northeastern State of Mexico at Tamaulipas. The outcrop of the Tertiary formations in Southwest Texas, in Wilson, Atascosa, McMullen, Duval and other counties, is naturally rich in oil, and the practical oil-men are risking their money in experimenting in this region. As the oil-bearing Tertiary strata extend east of the Mississippi into Mississippi and Alabama, it is not beyond possibility that oil may be found in these States."

The following data, showing the results of one year's exploitation, sufficiently confirm this declaration, which was received at that time with incredulity :

At Jennings, La., 150 miles east of Beaumont, a good flow of oil has been encountered. This well is 1,830 feet deep, and is described as a mild sort of "gusher." In the

*The exact extent of the productive ground of Spindle Top Hill has not yet been determined, because several of the largest corporations own large tracts on one side of the hill, where the limits have not been exploited. It is known that this field certainly exceeds 200 acres; and most of the oil-men think it will reach 300 or 325 acres. It is still occasionally widened by new wells.

morning it spouts about 35 feet, and at other times just high enough to make a good flow. Although this oil is accompanied by a great deal of sand which chokes up the well, it demonstrates the broad geological fact which I asserted. Practical oil-men have such faith in the locality that a dozen or more well-rigs are at work. The sand-problem is a mechanical difficulty which all are confident will be overcome.

Proceeding west from Jennings toward Beaumont, oil has been found in varying quantities at Lake Charles, near Crowley, and in one or two other places.

At Sour Lake, 25 miles northwest of Beaumont, oil has been known to exist since 1862; and a dozen years ago many pumping-wells were operated, and a small refinery was established. The field was abandoned; but after the Beaumont discovery numerous well-rigs were set up to penetrate to greater depths. From seven to eleven different oil-strata were passed through, and in August, 1901, a well, similar to that at Jennings, was obtained by the Guffey people. Its product has not been reported.

On March 7, 1902, another great oil-strike was made at Sour Lake, at a depth of 685 feet, by the Atlantic & Pacific Company. It is said that the oil shot 150 feet into the air, and was of better quality than that at Beaumont.

Twelve miles north of Sour Lake, at the village of Saratoga, where the oil outcrops at the surface as maltha, it is said that a good oil-well has been obtained, flowing several thousand barrels per day.

Rockland, north of Saratoga, is the next place where oil-deposits are found, and experimental boring has been going on here for some time. The sand-rock near the surface is completely impregnated with oil.

Between Sour Lake and Houston, 50 miles farther west, many experiments are in progress, but no success has been reported. In the city of Houston, I was informed by Major Cave, of the Houston & Texas Central Railway, that a small flow of oil had come from his well for many years.

Fifty miles south of Houston, near the mouth of the Brazos River, in Brazoria County, there is a field which,

according to Captain Lucas and the geological evidence which we possess, gives excellent indications for oil. There were no less than fourteen expensive well-rigs set up in this and Brazoria County, four of which were upon the remarkable hill known as Damon's Mound, one or two at Big Hill, and one at Keyser's Mound.

The wells on Damon's Mound encountered small flows of oil at depths of from 400 to 600 feet, exactly as at Beaumont; but so far they have been unsuccessful in securing a commercial flow.

At Keyser's Mound, in the same county, about 6 miles north of Damon's, and near the Brazos River, a flow of oil was struck at about 400 feet; but unfortunately the drillers were unable to cut off a tremendous flow of artesian water which was encountered just above it; and, as a result, the well produces to-day a remarkable emulsion of oil and water.

The well at Velasco (Bryan Heights) struck, at about 600 feet, a flow of gas so violent that its roar could be heard for miles. As a gas-well, this was as remarkable a phenomenon as were the Spindle Top oil-"gushers." The flow of gas could never be controlled; the well had to be abandoned, and a new hole, started beside the old one, is now giving every indication of securing oil.

Proceeding southward throughout the vast desert of the Lower Rio Grande, small quantities of oil have been encountered at several places, while still farther southward, at the end of our Coastal Plain, some miles from Beaumont, authentic reports have recently been received that flowing wells have been developed at Tampico, Mexico. Even as far south as the State of Tobasco, two flowing wells are reported. These results of a single year, although still fragmentary, are sufficient to reinforce our belief that in the future years the Beaumont field will furnish other profitable localities of commercial oil beside Spindle Top.

A Year's Development.—On January 10, 1902, one year from the date of the discovery of oil, there were 136 wells on Spindle Top. Operations for the first three months of the second year show a great increase; the number of "gushers"

has grown from 136 to 214, and more wells are drilling at present than at any previous time.

Three pipe-lines have been finished, two to Port Arthur (19 miles) and one to Sabine (24 miles). Pipe-lines to Beaumont to New Orleans and Beaumont to Galveston, Houston, and other Texas points, are contemplated.

On March 1st, the tank-storage exceeded 5,000,000 barrels. Among the tanks of 37,000 barrels capacity and over were twenty-two at El Vista, twenty-eight at Gladys, and thirty-three at Port Arthur.

The demand for tank-cars has constantly increased. In February, 1902, 500 cars were added, making a total at that time of 1,500. The Southern Pacific Railway has since purchased 250 tank-cars of 12,850 gallons capacity each, and many of the cars have already arrived at the loading racks. Many companies now have ample shipping facilities. In addition to the regular tank-car lines, there are between 800 and 1,000 tank-cars owned by local oil-companies. A huge tank-car factory is being erected at Beaumont to supply the demand.

Tank-steamers also have been in great demand. Many ships have cleared from Port Arthur; but the supply nowhere approximates the demand. The Guffey Company is constructing five steamers, one of which, to carry 60,000 barrels, is the largest ever made in America, and will equal any in the world.

The Guffey Company already has two refineries completed at Port Arthur, and another approaching completion. Work on five other refineries is progressing rapidly. Guffey Refinery No. 3, at Port Arthur, will have a capacity of 2,500 barrels per day. This company will ship no crude oil, but will bring the flash-point up from 120° to 145° and 150°, by taking out naphtha and kerosene before shipment.

Within a year from its discovery, Beaumont oil is burning in Germany, England, Cuba, Mexico, New York and Philadelphia. By its energy steamers are being propelled across the ocean, trains are hastening across the continent, electricity generated and artificial ice frozen in New York, ores ground and stamped in Mexico, Portland cement manu-

factured in Havana and Texas, and gas enriched in Philadelphia; and this, too, while half the world is either unaware or incredulous of the value of this fuel.

A strong demand for the oil comes from the manufacturers of illuminating gas. In March, this demand from New York and Philadelphia was great enough to justify a daily steamer from Port Arthur to those cities. The oil is also being sent to Atlanta and other cities for this purpose.

Many of the great railway lines of Texas have changed or prepared to change from coal to oil as fuel for their locomotives. The oil is also being used in hundreds of small factories in Texas, such as breweries, brickyards, etc. Even the farmers are using it as a fuel sufficiently inexpensive to permit of pumping for irrigation.

The production of the Beaumont oil-field during its first year was limited for the lack of means of distribution. It is estimated, however, that 5,500,000 barrels were actually drawn from the great reservoir—one-half of which was stored in tanks and the remainder consumed, shipped or wasted.

The shipments for 1901 were 1,750,000 barrels; for the first three months of 1902 they exceeded that total, those for March alone being more than 800,000 barrels. The field will probably ship 20,000,000 barrels in 1902.

It is estimated that the development of this field has cost \$7,000,000, of which about \$1,250,000 has been paid for labor. The tubing and well-drill rigs have cost, approximately, another million. Pipe-lines, lumber for derricks, and tanks for storing the oil, have consumed the remainder.

The average cost of sinking a well at Spindle Top is \$7,249. The 215 wells that are "in," together with the adjacent "dusters," have cost fully \$2,000,000. Probably \$50,000,000 more have been expended for purchases of land, transportation facilities, and other legitimate purposes. The capitalization of the 200 companies in the field is placed at \$200,000,000.

Before Captain Lucas's well came in, land could be purchased anywhere in the Coast Prairie country for less than \$4 an acre. Millions of acres have since changed hands at

fabulous prices, while every foot has been leased for favorable considerations. Thousands of acres of this land 150 miles from Beaumont have sold for as much as \$1,000 per acre. Land within the proved field has sold for nearly \$1,000,000 an acre; \$900,000 having recently been paid for one acre. No sales were made for less than \$200,000 per acre. Spindle Top to-day may be justly assessed at a valuation of \$500,000 an acre, or \$100,000,000. Two years ago it could have been bought for less than \$10 an acre.

The 214 wells upon the field are owned by about 100 companies. It is estimated that 120 of the wells are located upon 15 of the 200 acres of productive territory. These wells are in the hands of nearly as many individual companies, mostly small organizations without means for operation or facilities for outlet and transportation. The remainder of the territory is within the hands of four or five legitimate operators, who not only possess wells, but tank-cars, pipelines, refineries, etc., for handling and marketing the oil.

[To be concluded.]

Notes and Comments.

CANYONS AND SIERRAS OF THE GREAT SOUTHWEST.

On Friday evening, February 14th, under the auspices of the Franklin Institute and Y. M. C. A. at Association Hall, Prof. Robert T. Hill, of the U. S. Geological Survey, lectured on the above subject. Mr. Hill was formerly State Geologist of Texas and professor in the University of that State. He is well qualified to speak on this subject, as his expedition was the first to explore the canyons of the Rio Grande in Texas, some of which have vertical walls over 1,700 feet in height and contain some of the wildest and most rugged scenery in the United States. Before describing his journey, Mr. Hill gave a general description of the cordilleran, or elevated region of western United States. It is divided into three parts: First, the high forested mountainous region; second, the high plateau country of Utah, Arizona and New Mexico, and, third, the great deserts of the Southwest. The great problem of the deserts is irrigation, and while enormous areas favorably located as regards watersheds could be successfully irrigated, still, contrary to popular opinion, the greater parts of these deserts could never be irrigated either by artesian wells or impounding streams, or building dams across canyons and ravines to store water. The rainfall of the deserts is less than 15 inches per year, and on the Colorado Desert, in Southern California, the rainfall is less

than 3 inches per year. When we consider the fact that it takes from 25 to 100 acres of watershed to collect enough water to irrigate one acre of land, the hopelessness of the task in a greater part of the arid tract is readily understood. Then, again, 60 per cent. of stored water in the arid region is lost by evaporation. The air is so dry that it takes up water like a sponge, and loss by evaporation is very rapid. It is a common practice to cover ponds near windmills on certain ranches with boards to lessen evaporation. Parts of the desert of the Colorado, in Southern California, are hotter and drier than any deserts in the world. And yet, notwithstanding this fact, 150,000 acres at Salton are now being irrigated by flooding the section with the waters of the Colorado, which empties into the Gulf of California. This tract will now produce everything that can be grown in a sub-tropical country—figs, oranges, limes and apricots grow luxuriantly.

When this river overflowed its banks a few years ago, and ran across the desert, it was soon carpeted with green grass, and the cattlemen soon had thousands of cattle feeding on this new-made grazing-ground. The desert is not always barren. When the slight rain falls, wild flowers and the resurrection plant spring up, and young cacti and mesquite push their heads above ground, and for a time, at least, the desert blooms like a garden, soon to be blasted by the burning sun and shriveled by the dry air. Southern California, the land of sunshine and flowers, is merely a reclaimed desert. When the Spanish traveled north from Mexico and settled in the valleys, under the guidance of the padres, they began to irrigate and reclaim what is now called by some the garden-spot of the United States. Some years ago the U. S. Geological Survey, under Powell, surveyed and mapped out areas of deserts in the States of the Southwest which are available for irrigation, and the subject is again being agitated by Congress at the present Session. Mr. Hill showed a beautiful series of rare desert-views in various parts of Texas, New Mexico and Arizona, and spoke of the fauna and flora of these arid wastes. In the plateau country, mesas, or flat table-topped plateaus, are characteristic. And in New Mexico volcanic necks and stumps stand out bold and prominent on the desert. The desert is scarred in places with enormous lava-flows, whose jagged cindery masses extend for miles. Some of these flows are so fresh as to prove that it was but a few years since the flows poured across the desert. The typical bad man and treacherous Indian are to a certain extent things of the past, and one can now stand on the mountains near Bisbing, Ariz., and see the stacks of the smelters of three of the largest copper mines in the world, and yet it is but 15 years ago that Geronimo and his band of cruel Apaches held full sway in this region. The railroads of these mines now parallel the Southern Pacific Railroad for 75 miles or more through one of the finest copper regions of the world.

The deserts of Texas support thousands of cattle; they are good grazing lands when not available for irrigation. The State leases the lands to the cattlemen for 6 cents per acre and the revenue goes to the school fund of Texas. After this general description of the deserts Mr. Hill gave a detailed account of his perilous journey through the wilderness of canyons of the Rio Grande. He was sent by the United States Geological Survey to study the geology, but principally the topography of the region and to learn among other things why the river took the peculiar course it does across the moun-

tains and plateaus of Texas. It may be classed as one of the great rivers of the country, as it is over 1,400 miles in length. It rises in the mountains of Colorado, where it is fed by the snows of the Rockies; but when it leaves the Rockies its course is across the desert, and for 1,400 miles only three streams feed it.

Mr. Hill discovered that one important source of supply in the canyon region was hundreds of hot springs which came up in the bed of the river and probably supplied one-third of the volume of the water. Another curious fact is, that for nine months of the year, at El Paso, Tex., it is a lost river; that is, the bed is dry until it is fed by the melting snows and rains from the mountains, when it is a roaring torrent. The region of the river explored by Mr. Hill was through an unknown country. His boats were made in Texas and transported many miles by rail and wagon to the river. His party of five consisted of his nephew, who served in the Cuban War, a trapper who knew parts of the country, and two adventurous Texans. The expedition entered the river at Presidio Del Norte and traveled for several hundred miles until they reached the Pecos River. For many miles it is a canyon country with steep precipitous walls from 500 to 1,700 feet high, so that one is virtually a prisoner for many miles when he enters the river. And even at places where the plateau top can be reached, the arid desert stares them in the face.

To cross this waste to the nearest far-distant settlement without ample water and food means starvation, so the only alternative is to continue the journey when the start is made down the river. The river is full of rapids and cascades, and jagged rocks protrude above the foam and make navigation very dangerous—only strong and skilful boatmen can succeed. Not only this, but long portages must be made; so that after leaving Presidio two months elapsed before the branch known as the Pecos was reached. The scenery of these canyons is rugged and grand, even to one familiar with the grandest canyon and plateau scenery of Arizona and Utah. Enormous chalk cliffs were noted and frequent intercalated beds of lava were met with. In some places the river was so narrow and the walls of solid rock so high and precipitous that the sunlight could barely be seen 1,000 feet above. Mr. Hill has the credit of exploring a new section of country about which nothing was previously known. His report to the Government will be read with interest. Game was very abundant and plenty of black deer were shot. Ducks were plentiful and were an article of diet for a couple of weeks, until the expedition was surfeited, when no one could be tempted to eat them. A new species of Rocky Mountain sheep, different from the more northern neighbor, was discovered by the party.—*Oscar C. S. Carter.*

The American Electrochemical Society will hold its second general meeting at Niagara Falls, N. Y., beginning Monday, September 15th, and extending to the 17th, or possibly to the 18th. The local committee will provide interesting excursions and exhibitions of the local electrochemical industries, which will be an important feature of the meeting. A number of important papers are already promised, and the prospects are that the meeting will be even more successful than the inaugural meeting at Philadelphia. Entertainment will be provided for ladies.

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Mining and Metallurgical Section.

[*Joint meeting of the Section and the American Institute of Mining Engineers, held at the Manufacturers' Club, May 14, 1902.*]

The Metallurgy of Titanium.

BY AUGUSTE J. ROSSI.

We cannot expect, within the limits of this paper, to treat this subject exhaustively, but will endeavor, in the following, to present it in as concise a manner as is consistent with a clear exposition of its importance.

Ores of titanium, titaniferous iron ores [that is, iron ores containing a notable amount of titanic oxide (TiO_2)], say not less than 5 per cent., generally 10 to 20 per cent. and frequently more, up to 40 per cent. or thereabout, occur all over the world in immense quantity, "in mountain masses," constituting in some localities, as in Sweden, Norway, Canada, the Adirondacks (N. Y.), in North Carolina and other States of the Union, the geological formation itself, the igneous rocks having, in many places, been so permeated with the metallic oxides as to justify their being called iron ores.

As a rule they are Bessemer ores, quite free from phosphorus and sulphur, though not invariably so. When the percentage of titanic oxide is very high, that of the iron is low, but the proportions do not necessarily vary in the same ratio; that is, a rich ore may contain more titanic acid than one lower in iron. The percentage of iron varies, being as low as 35 to 36 per cent. in real ilmenite. It is more generally not less than 50 to 55 per cent., reaching often an average of 58 to 60 per cent. and as high as 63 to 65 per cent.

It is obvious that if these ores were to be considered in the same light as other iron ores, equally rich in iron, they would form an excellent stock for blast-furnaces for years to come, as their supply might be called inexhaustible, and they could take the place, in part or wholly, of other iron ores free from titanium, of which the exhaustion, in a comparatively short time, in certain districts can be foreseen, owing to the tremendous demands made on them by our modern monster blast-furnaces. In this sense we are justified in saying that the metallurgy of titanium is one of pre-eminent importance, as it implies the use of these ores, which may justly be called the resources and reserves of the future, when they will be appreciated at their full value, and the prejudices against them will be removed, as gradually they are getting to be. "The verdict against them" as it has been said by others than ourselves in the discussion of some of our papers on the subject, read before the American Institute of Mining Engineers, "is unjust, based on entirely insufficient grounds and far from creditable to the progressive spirit of American metallurgy."

Generally low in silica, free from impurities, such as phosphorus and sulphur, they are particularly well adapted in the blast-furnace for the production of a stock well suited for the open-hearth process (either acid or basic), which is gradually supplanting, at least competing more seriously with, its rival, "the pneumatic or converter process."

Some of the objections raised against the use of these ores in the blast-furnace are so unreliable, so contradictory, so much in opposition to actual facts, that it is really

puzzling to find out on what ground they were originally founded.

Opinions in this respect seem to have been taken already made, without any personal control or even desire to ascertain the authenticity, reality or importance of certain statements, and handed down from one to another.

We have not been able to find one metallurgist who could tell us he had used these ores or that, using them, he had experienced any trouble thereby. They have brought forward the stereotyped objections and rested there: "*Sit pro ratione voluntas!*"

These objections have appeared in many scientific publications (easily quoted), and often simultaneously with their refutation by actual experiments on the subject. For instance, to mention one of them, it has been stated that the presence, in a blast-furnace slag, of 1 per cent. of titanitic acid, or thereabout, was sufficient to render it so infusible as to transcend the heat capacity of the blast-furnace, the slag being so pasty as to render its tapping impossible or practically so; and still, slags, containing 25 to 35 per cent. of titanitic acid have been run for over twenty years from blast-furnaces put up in the Adirondack wilderness some fifty years ago, and thousands of tons of such slags which we have seen and analyzed, form, at the present day, an embankment around the cast-house of the old furnace, of 15 tons daily capacity, still standing as a testimony that this statement as to infusibility of titanitic slags cannot in any manner be sustained.

For seven years blast-furnaces have been run in England, at Norton-on-Tyne, with ores containing 40 per cent. of titanitic acid and 35 to 36 per cent. of iron, making 200 tons of pig-iron per week. Analyses of the slags have been published by the chemist in charge, as well as all the data as to composition of ores, charges in coke, ore and fluxes. The slag contained, on an average, 36 per cent. of titanitic acid.

We ourselves have run for several months a small blast-furnace of 3 to 4 tons capacity, put up at Buffalo, to demonstrate the economy of the smelting of this class of

ores, when properly dealt with. We have tapped hundreds of tons of slags containing 32 per cent. titanic acid, which ran 50 feet from the furnace perfectly liquid. In crucible tests we have made in a furnace with "natural draft," compounds containing 63 to 64 per cent. of titanic acid were obtained, which we have been able to cast in molds.

We give below an analysis of the slags mentioned above as an illustration:

	I.	II.	III.	IV.
Silica	27'83	26'72	15'90 to 17'50	0 67
Titanic acid	36'18	25'11	34'38	64'80
Lime	24'36	25'81	22'10	14'30
Alumina	9'18	11'86	11'23	10'50
Magnesia	0'60	5'99	9'70	8'30
Oxide of iron	1'86	3'46	4'30	0'90

I. Slag run at Norton-on-Tyne from Norwegian ilmenite containing 40 per cent. titanic acid, 35 to 36 per cent. iron. Analysis by chemist in charge. Wm. M. Bowron, *Trans. A. I. M. Eng.*, Vol. XI, p. 159.

II. Slag run in Adirondacks in 1856. Average specimen from several hundred pounds of slags picked up from the cinder bank in 1893 by A. J. Rossi. Analysis by Ledoux & Co.

III. Slag run in the small Buffalo furnace, put up in 1896, at the New York Car-Wheel Works by A. J. Rossi. Analysis by the chemist of the works.

IV. Compound made in crucible in a furnace with natural draft and poured out in molds. The ores used contained 15 per cent. TiO_2 , and on an average 58 per cent. iron.

Other objections, such as "titanium deposits," in the boshes, according to some; in the hearth, according to others, have been advanced against the use of these ores, and, to accept the "sworn testimony" of some blast-furnace managers in a suit in which we were called as expert, " $\frac{3}{4}$ of 1 per cent.," " $\frac{1}{4}$ of 1 per cent.," mere "traces" of titanic acid in an iron ore, are as sure to produce these deposits as larger percentages. We have been for twelve years technically in charge of the blast-furnaces of the Boonton Iron Works (Fuller, Lord & Co.), in 1876. Our ores contained normally from $\frac{3}{4}$ of 1 per cent. to 1'25 per cent. titanic acid, and never did we observe such deposits in our two furnaces. We did not even at that time attach importance enough to the presence of titanic acid cinder ores to determine it in our analyses otherwise than as a curiosity.

As regards larger percentages of titanic acid the suc-

cessful and continuous running of the Adirondack furnaces for twenty years, that of the English furnace at Norton-on-Tyne for seven years (as attested by a mention of this furnace in a paper read before the British Iron and Steel Institute at their annual meeting in 1894), that of our own small blast-furnace at Buffalo for some months, ought to dispose of these objections, or at least limit them to special cases, as when, by accident, the objectionable phenomena might have been observed in an abnormal and deranged working of a furnace; smelting, possibly unknowingly, a mixture of ores in which titanitic acid was present; and it might well be asked whether such derangement was not *post hoc* rather than *propter hoc*.

It is well known that obstructions of a similar character and composed almost entirely of lime have been observed in the smelting of ores free from titanium. One of these infusible blocks in a blast-furnace was stated to weigh 30 tons. The cause of their formation has been attributed to the excess of limestone charged as flux and of lime in the cinder; very basic silicate of lime being quite infusible *per se*. In such conditions titanium deposits may have contributed to the obstruction without being the cause of it.

Some twenty-five or thirty years ago the chemist was a luxury in a blast-furnace plant. A good practical rule of thumb was followed with sufficiently constant success with ores varying but little year after year; but when the demands of industry justified an increase in the number and size of furnaces and consequently necessitated a more abundant supply of ores, new ores had to be mixed with those generally used, and the presence of titanitic acid being lightly ignored, as well as the manner of dealing with it properly, fluxes may have been indiscriminately added, causing trouble, and the titanitic acid was conveniently made the scapegoat. When we say fluxes, we mean calcite, as, for many years, limestone (calcite) was considered the only admissible or safe flux in a blast-furnace. Indeed, Percy himself, in his admirable and classic book on metallurgy, states that, "as magnesia increases the infusibility of a slag, dolomite as a flux, instead of limestone, should obviously be avoided."

This is another prejudice which has lasted for years and has been exploded only within the last twenty years or thereabout. As every metallurgist knows now, dolomite is preferable to calcite as a flux, as it increases the fluidity and fusibility of the slag, at the same time removing sulphur fully as efficaciously if not actually better than lime.

Titanate of lime is more infusible still than silicate of lime, and the addition of lime in excess, on general principles, may possibly, with ores very low in silica and containing a large amount of titanitic acid in the mixture, have caused the slag to prove less fusible; but we should not forget, however, that a silico-titanate of lime, containing about equal percentages of silica, titanitic acid and lime—"sphene," as it is called—is as fusible in a blast-furnace as any good foundry-iron slag and considerably more fusible than silicate of lime; so that the presence of titanitic acid should have increased the fusibility, if a sufficient amount of silica was present, instead of diminishing it. We may refer to Analysis No. I of the slags run at Norton-on-Tyne as an example.

As to "titanium deposits," to be called strictly so, that is, formations of nitrides and cyano-nitrides of titanium, of a copper-red color, or of a metallic titanium, as it was claimed by some, they may have been possible in a serious derangement of the working of a blast-furnace occurring under circumstances independent of its presence and due to causes entirely foreign to it; the titanitic acid being then an "accessory after the deed," and conveniently assumed to be the principal cause of the mischief.

We have seen in Pittsburg a very fine large specimen of such titanium deposit; it was copper-red and kept religiously under a glass case. But the well-known metallurgist who had it was conscience-stricken and owned frankly to us that he had had the curiosity to have it analyzed, and that it was found to contain $98\frac{1}{2}$ per cent. of copper. As is well known, for many years, and until the researches of Wöhler, it was believed that titanium was a red metal, like copper.

In short, titanitic acid, properly dealt with in the blast furnace, will not necessarily prove the cause of trouble.

Slags containing some 35 per cent. of titanitic acid will run as fluid as silica slags, and if in an iron ore the titanitic acid or oxide (TiO_2) be treated as so much silica, and be depended upon and calculated to form one of the principal elements of the slag, with such amount of silica as will be necessarily and unavoidably contributed to the slag by the limestone (as the ores and the ashes of the fuel), and if a dolomitic stone be used as flux instead of a calcite, titanosilicates of lime, alumina and magnesia will be found to form a very fluid fusible and good slag, and no titanium will remain in the furnace to cause any trouble in a normal or ordinary running.

It is this addition of dolomite as a flux, instead of calcite, with which we have experimented with success in our small furnace at Buffalo. (See analysis of slag III). Both in the Adirondacks (analysis II), and in England (analysis I), at Norton-on-Tyne, the composition of the slag was different, in this sense, that the silica was present to nearly an equal percentage with lime and silica, reproducing practically the composition of the mineral sphene perfectly fusible in the blast-furnace—a *silico-titanate of lime*. In England it was obtained by the addition to the ore, of which the composition is given below, of siliceous flux, in the shape of old bricks, besides the calcite addition, considered indispensable at the time.

REUSED AT NORTON-ON-TYNE—NORWAY ILMENITE.*

Titanic acid	(average of cargo) 39'20
Silica	5'70
Ferric oxide	18'59
Ferrous oxide	30'00
Manganese oxide	0'60
Alumina	2'89
Magnesia	2'80
	<hr/>
	99'78
Iron	36'34 per cent.

In the Adirondacks, siliceous fluxes were also added, but they were furnished by the Labrador feldspar, costing

* Analysis by Wm. M. Bowron, chemist in charge. See Bowron paper quoted above.

nothing and saving that much limestone. The ore on an average contained:

Silica	2'50
Titanic acid	13'50
Alumina	1'50
Magnesia	0'50
Oxide of manganese	0'13
Phosphorus	0'020
Sulphur	1'052
Oxide of iron	81'90
<hr/>	
Metallic iron	58'43 per cent.

We have published on these questions several papers*, to which we refer the reader for more complete information. In one of them will be found all the data of the run of the small experimental furnace erected at Buffalo.

We should remark here that all that we have said above applies to ores really titaniferous; containing, say, not less than 5 per cent. titanic acid, smelted alone. As to ores containing 1 per cent. of titanic acid or thereabout, our practice of twelve years in Boonton, N. J., and that of other furnaces who bought from us the same ores that we have used (or similar ones of Morris County, in which the average of titanic acid is from 0'55 to 1 per cent., such as those of the Hibernia Mine, Mount Pleasant), and are using yet, cannot leave any doubt that $\frac{3}{4}$ per cent. to 1 per cent. titanic acid in the ore mixture can be completely ignored so far as affecting in any manner the run of the furnaces or the charges.

But, even assuming an inferior limit of 0'50 titanic acid admissible in a mixture, it is difficult to conceive why ores from North Carolina and elsewhere, containing 64 per cent. of iron and 5 per cent of titanic acid, cannot be used in mixture with ores free from titanic acid to the extent of 10 per cent., since by so doing the mixture would contain only 0'50 per cent. titanic acid, an amount present in the charges of a number of blast-furnaces we could quote, and immense

*Titaniferous Ores in the Blast-Furnace. *Transactions American Institute Mining Engineers*, vol. xxi, p. 832. *Smelting of Titaniferous Ores. Iron Age*, Feb. 6th and 20th, 1896.

deposits of excellent ores would be made available as blast-furnace stock.

But prejudices are difficult to eradicate when they are deeply rooted, even if arithmetic is resorted to to demonstrate their fallacy.

There is another objection, more specious than real, which has been raised against the smelting of titaniferous iron ores, namely, that of the relative economy offered. There is no doubt that, with such ores as were used in England at Norton-on-Tyne, and which contained only 36 per cent. iron with 40 per cent. titanic acid and 10 per cent. of other gangue (in all, 50 per cent. of barren materials), the addition, as flux, of as much lime and as much silica as of titanic acid in the ores, there must have been something like $4\frac{1}{2}$ tons of slag to melt per ton of iron smelted, and the process may not have proved economical as to fuel; but would it have been any more so with ores free from titanium but containing such an amount of gangue and 40 per cent. of silica? In the Adirondacks, the ores being much richer and containing so much less titanic acid (15 per cent. instead of 40 per cent.), the addition of rock as flux did not very materially affect the economy; but in our small furnace at Buffalo, as no other flux but dolomite was added (the titanic acid being treated as so much silica), the smelting proved as economical (as the record of the run showed) as that of any other ore free from titanium and containing the same amount of silica as the Adirondack ores contained of titanic acid.

But this question of economy of fuel, assuming even it were real when dealing with such ores as it would be contemplated to smelt without admixture, that is, rich ores containing moderate amount of titanic acid, is of but little importance if, as we will see presently, the properties of the pig metal yielded by this class of ores are such that it commands a much higher price on the market than an ordinary good foundry iron.

It is the consensus of opinion, admitted even by those most obstinate in their prejudices, that the pig-iron smelted from really titaniferous ores smelted alone, or in important

proportions with other ores, is "strong," "wonderfully good," "a splendid iron," "all that can be desired," for such are the expressions met with at every step when one is referred to the literature of the subject. The iron made at Norton-on-Tyne in 1869-1876, it is said in the *Journal* of the British Iron and Steel Institute, "went to Sheffield for armor plates on account of the toughness that this iron not only possesses but imparts to others in admixture."

It is essentially an open-hearth stock. Analyses of the pig-iron made by us at Buffalo and that of the Adirondacks (the same ores were used in both cases) showed phosphorus traces; silicon, 0.11 to 0.13; carbon, from 1.86 to 3.50 practically all combined; the fracture had very much the appearance of that of steel. It is eminently a chilling iron, well adapted for car-wheel mixtures. Introduced into such mixtures, not only does it increase the strength of the metal constituting the body of the wheel, but it gives at the tread a deep, strong and hard chill, resisting attrition and shocks remarkably well, as was attested by parties interested in this line of manufacture, and for whom and with whom we have made extensive tests with this special iron.

Briefly stated, the results were as follows: The addition of 5 per cent. of titaniferous pig to a normal mixture for wheels increased the chill on chill blocks from 1.062 inches to 1.375 inches, and the transverse strength from 3,250 pounds to 3,775 pounds per square inch. The addition of 10 per cent. titaniferous pig brought the chill to 1.562 inches, with a transverse strength of 3,600 pounds per square inch; and the addition of 25 per cent. of this titaniferous pig, white or mottled white as it was, without affecting the original strength, raised the depth of chill to 1.750 inches.

In another establishment the wheel mixture showed a tensile strength of 24,500 pounds, and a transverse strength of 2,500 pounds per square inch. The addition of 10 to 15 per cent. of titaniferous pig to a cheap grade of foundry pig, showing only 18,500 pounds tensile strength and 1,900 pounds transverse, raised the strength to 25,500 pounds and 2,730 pounds, respectively, per square inch, with a much

deeper chill than in the wheel mixture, and at a cost of several dollars less per ton.

Strange as it may appear at first, this titaniferous pig-iron does not contain titanium to any important extent. Rarely does it contain more than a few tenths of 1 per cent.; more generally only a few hundredths of 1 per cent. The influence of titanium in the smelting would seem thus to be one of purification, by eliminating obnoxious elements more than a direct one; but we will see later on that it is not necessarily always so. Titanic acid is not reduced by carbon at the temperature attained in a blast-furnace, contrary to what happens with silicon. It requires the high heat of the electric furnace to secure such a reduction. If titanium is found in the pig-iron, to some small extent it is due, according to certain special reactions, possibly to the presence of alkaline cyanides formed in the blast-furnace in the vicinity of the tuyeres, forming small quantities of cyano-nitride of titanium, which is carried out by the iron, coating it *superficially*, as it has been observed in some furnaces, and giving to the pig-metal a copper-colored hue. This may possibly explain why titanium is found in such small percentages and why it is not found in the free *metallic* state in the analysis, but as *carbide* and *cyano-nitride*, or both. That titanitic oxide is not reduced directly by carbon in the blast-furnace and, if at all, but to a very small amount, seems to be proved by the fact that ores containing as much as 40 per cent. of titanitic oxide yielded a pig-iron containing titanium 0.00 to 0.03 per cent. (analysis of pig-iron smelted from ilmenite, made at the School of Mines of Paris), while the pig-iron smelted from the Adirondack ores containing 13 to 15 per cent. titanitic oxide (TiO_2) analyzed 0.07 to 0.12 per cent. titanium; the conditions of running of the furnace in both cases seem to have had more to do with the reduction, small as it was, than the percentage of titanium in the ores.

The question suggests itself: Since pig-iron smelted from titaniferous ores, though containing but very small amounts of titanium, and that not in the metallic state but as carbide or combined with nitrogen and carbon as cyano-nitride,

what would be the effect of the presence of titanium as metal, in such products as cast-iron or steel, in more important percentages?

We know that nickel added to steel, to the extent of 3 to 5 per cent., imparts to it valuable properties; that even added to cast-iron it increases the strength, though at a material increase of cost. We know also that chromium and molybdenum have special influences on the properties of steel. Could not titanium, as a metal, secure valuable though different or similar properties? But since pig-iron does not appear to contain any titanium to an available extent, and that amount not even as free metallic titanium, and that, whatever may be this quantity, it disappears in the process of refining pig-iron for making steel, the only way to secure the presence of titanium to any important extent in pig-iron or steel is to add it to the finished product in the state of alloy, as *ferro-titanium*, in the same manner as ferro-chrome or ferro-nickel or ferro-manganese is used to incorporate these metals in steel. Such alloys we have manufactured last year by the ton, and of this manufacture we will now briefly speak:

Professor Moissan, in his well-known experiments on the reduction of refractory metallic oxides, has been able to obtain small quantities of metallic titanium by the reduction of purified rutile (titanic acid, TiO_2) by carbon, in a lime or magnesia crucible, under the influence of the heat secured by a powerful electric current. Moissan's method of using a small furnace, with horizontal electrodes, between which the electric arc was started *above* the materials to be reduced, and not in contact with them, has become classical. But the product obtained contained carbon, and was indeed carbide of titanium for a great part, and had to be purified by repeated treatment with fresh quantities of titanic oxide. Such experiments, although of great interest in the laboratory, could not, of course, form the basis for the production of commercial titanium alloys, as the low price of a product is a *sine qua non* of its practical use. Furthermore, titanium carbide, as obtained by Moissan experimentally, on a small scale, and which can

be obtained on a larger scale much more easily than the metallic titanium, contains *titanium combined* with carbon in definite proportions. It has special properties, principally of hardness, which it may impart to mixtures; but whether valuable, as they may be, are quite different from such properties as could be expected from titanium introduced in a metal (such as cast-iron and steel) in the free metallic state, as is nickel, for instance.

By the method we have followed we have manufactured alloys of titanium and iron, containing from 10 per cent. to 75 per cent. of titanium, and either practically free from carbon or, if containing carbon, containing the latter in the *graphitic state* so that the titanium was present as *free metal* alloyed with iron and not in the state of carbide.

As the percentage of titanium in these alloys increases, their fusibility diminishes. Thus, 10 per cent. titanium alloys do not melt at the temperature of fusion of cast-iron and steel, and they are incorporated in the molten mass by a sort of dissolution just as platinum, infusible at the above-mentioned temperatures, "will fuse in contact with steel at a temperature at which even the steel itself, if not affected, alloying in all proportions with iron," as shown by the results obtained by Faraday and Stoddart. Ten per cent. titanium alloys containing carbon (graphitic) present the appearance of a No. 1 graphitic pig-iron, the particles of graphite shining brilliantly through the mass; they are soft under the hammer, forging and flattening though quite resisting. However, when once torn apart, so to speak, in small fragments, they flatten to such an extent as to admit of their being easily pulverized. The powder, sifted through an 80-mesh sieve, showed by analysis the same percentage of titanium as the solid piece itself, thus demonstrating a very even dissemination of the graphite through the mass. As the percentage of titanium increases, the grain of the fracture becomes closer, the other characteristics remaining the same.

The titanium alloys, free from carbon, are of a silver-white color, exhibiting a coarse crystalline structure, when the titanium is low (about 10 per cent.), the grain becoming

finer as the titanium percentage increases. With 35 per cent. titanium the fracture is that of a solid mass, showing no crystallization, at least to the naked eye. The color is of a dull silver-white when the alloy contains over 45 per cent. to 50 per cent. titanium.

All these alloys, the carbon alloys as well as the others, are much lighter than cast-iron, their specific gravities varying with the amount of titanium. We have found it to be 5.60 for a 25 to 30 per cent. alloy free from carbon, and about the same (5.74) for a 10 per cent. to 12 per cent. alloy with carbon; metallic titanium having a specific gravity of 4.87, cast-iron one of about 7.00 and wrought-iron one of 7.788.

It would carry us too far to describe in detail the manufacture of these alloys, and we refer the reader to the article on this subject which has appeared in Vol. IX *Mineral Industry*, 1901. We will briefly recapitulate its salient points:

The electric furnaces we used were of the well-known type of the Siemens furnace of 1879, modified, to some extent, for our purpose. It consisted essentially of a large block or parallelopiped, as of agglomerated graphite, properly insulated with refractory materials of bricks. A cavity in the block formed the crucible or hearth, and in this cavity, by means of a proper system of chains, pulleys, etc., the vertical carbon electrode or cathode, formed of one or several carbons bunched together, could be worked up and down. The graphite block was connected at its lower part with one of the terminals of the current and formed thus the anode, while the vertical carbon, by means of flexible cables, was connected with the other pole; the materials to be reduced being charged in the cavity of the furnace, and the vertical carbon lowered to almost a contact, the arc was started through the materials of the charges, and the reduction proceeded until completed. The product could be removed at the end of the operation, or the alloy (when liquid) tapped off.

According to size of cavity or crucible, intensity of current and percentage of titanium desired, we could make from

150 to 250 pounds of alloy in about two hours with about 200 horse-power. When making alloy containing carbon, the charges consisted of the titaniferous oxides mixed with the proper amount of carbon, the materials being used in powder and strongly compressed. Some of the ores used were the Adirondack ores mentioned above, which could yield readily an alloy containing from 12 to 13 per cent. titanium. By using Canadian ores containing 35 per cent. titanic acid and about 35 per cent. iron, we obtained alloys containing as much as 35 per cent. titanium. The use of rutile—natural titanic acid—nearly pure and containing some 90 to 95 per cent. of TiO_2 , would of course have given us alloys as high in titanium as might have been desired, but, until the late discoveries of special, extensive and geologically interesting deposits of rutile in Virginia about one year ago, its cost, \$250 to \$350 a ton, excluded it, from the standpoint of economy. Even now, and though the price of rutile has fallen to fully half of what it was, this price is considerably higher than that of titaniferous ores—high in titanium (40 per cent. titanic acid), which can be had at the cost of ordinary iron ores.

We have obtained from the Adirondack ore containing 58 per cent. iron and 15 per cent. of titanic acid (TiO_2) or say 9 per cent. of titanium, alloys of 75 to 80 per cent titanium by the special method which we have followed, which is a sort of igneous concentration, as we have called it. It consisted in submitting at our furnaces a mixture of these Adirondack ores with a quantity of carbon sufficient to reduce the iron oxides it contained, but not the titanic oxides, to a heat but a little higher than that attainable in the blast-furnace, adding to the ore a small quantity of lime or good limestone so as to form practically, with the titanic acid of the ores, a titanate of lime, with such small amount of magnesia and alumina (or silica) the Adirondack ores could contribute to the slag. We thus obtained, as a by-product, a titaniferous pig-iron, containing now but a few hundredths of 1 per cent. (0.032 per cent.) of titanium possessing all the valuable properties of the metal smelted in the blast furnace from this class of ores and, at the same time, as slag, a con-

concentrate of the titanitic acid of the ore to the extent of 56 to 58 per cent. TiO_2 , with no more iron in this slag than is ordinarily met in a blast-furnace cinder; that is, about 2 per cent. iron, 56 per cent. titanitic acid, corresponding in round numbers to 31 per cent. titanium. Thus by treating 100 parts of this concentrate as we did the ore, we could theoretically obtain an alloy containing, say 31 per cent. titanium acid, 2 per cent. iron, or 94 per cent. titanium, or, by mixing it with proper quantities of iron ore, any percentage of titanium desired. But, as we will see, this concentrate proved of a particular value when making alloys free from carbon.

All the alloys made with carbon, as reducing agent, contained from 7.50 to 8.50 per cent. carbon and occasionally even 9 per cent., of which 0.10 per cent. or less was combined carbon, the remainder graphitic carbon. In order to obtain alloys free from carbon, or practically so, we used a method based on the well-known property of aluminum to reduce metallic oxides. This property has formed the subject of many experiments in the laboratory for over fifty years, but it has been considered necessary for success to use the aluminum as an impalpable powder and to mix it, in that state, with the powdered oxide to be reduced.

Of recent years Dr. Goldschmidt has succeeded in utilizing industrially to a certain extent the reducing power of aluminum in pulverulent form. This method consists, after having mixed intimately together the powdered aluminum and the powdered oxide, in placing in the mass a primer formed of powdered aluminum and an oxide capable of readily yielding a portion of its oxygen, such as sodium or barium peroxide, starting the primer itself by igniting an inserted ribbon of magnesium. The heat of formation of alumina (in the primer), the aluminum oxidizing at the expense of the oxygen of the oxides, is so intense that, by contiguity, it is imparted to the whole mass and the reduction proceeds instantaneously, so to speak, often tumultuously and dangerously so, without the intervention of any external heat. It is not for us to discuss the value of this process any further than to say that the rapidity of the reaction

itself creates in the metal or alloy obtained a certain uncontrollable amount of aluminum which cannot be removed without a remelting of the product, and that some of the materials of the vessel in which the operation is carried on passes also into the product—silica, if a clay vessel be used; carbon, if a graphite one be resorted to; so that it cannot be claimed to produce strictly pure alloys or metals. But the main drawback to its industrial use on a large scale, aside from the manipulations required, is the original cost of the aluminum in powder, which is several times that of aluminum in ingots or scrap.

We have found that it is not necessary to use the aluminum in powder to secure the reducing action, but that if a bath of aluminum be maintained at the proper temperature, in an electric furnace, for instance, like the one mentioned above, the metallic oxides (the titanous acid in the case and the iron oxides charged in this bath) will be reduced, the temperature rising from the heat of formation of alumina to such an extent as to allow the moderation of the external source of heat first applied until the reduction is complete or nearly so. The metal or alloy obtained can then be kept liquid by increasing the intensity of the current before being tapped, and easily deprived, by a fresh addition of oxide of iron, of the aluminum it may contain, or, by proper additions, of any other impurities it may be considered desirable to remove.

Furthermore, in the Goldschmidt process, if titaniferous iron ores are used as raw materials, the amount of powdered aluminum to be added must be such as to reduce also the oxides of iron, which is paying rather dear per pound of iron reduced (as it requires nearly one-half pound of aluminum per pound of iron), unless rutile be used, and then its price comes as a very important factor.

By using, in starting, the titanous concentrate mentioned above as containing some 30 per cent. titanium and 2 or 3 per cent. of iron only, we have only to add aluminum to reduce the titanous acid, and if lower alloys are wanted, dilute, so to speak, the high alloy obtained, in a bath of iron. We have thus manufactured alloys of titanium containing from

10 to 75 per cent. titanium and from 0.10 per cent. to 0.60 carbon or thereabout at a cost not materially higher than the carbon alloys.

In the tests we have made of the titanium alloys for seasoning cast-iron, we have invariably used the carbon alloys and, by preference, alloys containing 10 to 13 per cent. titanium. In an experiment with steel we have used the alloys reduced with aluminum and practically free from carbon.

We have added the carbon alloy to cast-iron in crucible in lumps; in the ladle in small pieces or in powder; in the cupola in large lumps and also in powder, and the results have been practically the same. An addition of 3 per cent. or thereabout of a 10 per cent. titanium alloy appears to be amply sufficient to secure such results as an increase of 20 to 30 per cent. in the tensile strength of cast-iron, and proportionately as much in transverse strength. Results of such tests have appeared in papers read by us before the American Society of Mechanical Engineers (Milwaukee Meeting, May, 1901, Vol. XXII, of *Transactions*) and at the Annual Meeting of the American Foundrymen's Association, June, 1901, Buffalo, Vol. X, *Transactions*, Part I, to which papers we refer the reader.

Since then we have made other equally successful tests in different establishments, car-wheel works and others. We will briefly recapitulate them:

In general, the results of tests of 100 bars square 1 x 1 x 12 inches between bearings, and round $1\frac{1}{8}$ inches diameter by 18 inches long, or thereabout, showed that by adding in the cupola, in good-sized lumps, 3 per cent. of a 10 per cent. alloy, or the same amount in powder in the ladle, we could bring the original strength of a good No. 2 coke-iron, showing 24,500 pounds tensile and 2,450 pounds transverse strength per square inch up to that of an excellent Scotch charcoal pig-iron or higher (in fact, 28,800 pounds tensile and 2,900 pounds transverse); and that by a similar addition of alloy to this Scotch charcoal pig we could bring the strength to some 32,500 pounds tensile and nearly 3,300 pounds transverse strength. As the price of this charcoal

pig-iron was \$29 while that of the coke-iron was \$15 at the time, and as they were used in mixture for special foundry purposes, it is clear that a mixture of the coke-iron treated with the alloy and of the coke-iron itself not treated, could be used with great advantage as to cost of mixture for the same strength secured; the addition of the the alloy to the extent mentioned to the coke-iron increasing the cost of the latter but a fraction of the difference of prices (\$15 and \$29) between the two original pig-irons.

Our tests with steel have so far been limited to crucible steels, and enough has been observed to show that the influence of titanium, introduced in steel in the metallic state, has been to increase considerably the ductility, as proved by the remarkable elongation, contraction of area and limit of elasticity observed in high carbon steels containing 1.25 per cent. and even 2 per cent. carbon. The quantity of titanium found in the steel by analysis varied from 0.89 per cent. and 10.1 per cent. to 0.10 per cent. As the effect of even such small quantities as the latter one (0.10 per cent.) was very marked, and as, in these cases, 0.10 per cent. did not represent what could have been expected from the addition of the alloy, the question arises: Has not titanium an indirect action, when thus added to steel, besides a specific one?

It has been suggested that in the same manner as manganese removes oxygen from steel in the Bessemer process, as also in the open-hearth and even in crucible steel, titanium may not only act as a deoxidizing agent—much more powerful still than manganese—but also as removing from the steel the nitrogen it undoubtedly contains and which has an unfavorable influence on its strength. The odor of ammonia so noticeable in the open-hearth process proves the presence of nitrogen very decidedly. As is well known, titanium burns in nitrogen at 800° C. with incandescence, just as iron burns in oxygen. If so, the use of the alloy, even when containing carbon, would be well indicated in the open-hearth as also in the converter, since it could be used as a recarburizer, on account of the high percentage of carbon it contains; as a deoxidizer (with or without ferro-

manganese); and as a denitrogenizer, so to speak; and, in the case of small converters for steel castings, the heat of formation of titanitic acid, which is much higher than that of silica, would prove advantageous in raising the temperature of the bath even were but a small percentage of titanium to remain ultimately in the finished product. If by such use open-hearth and converter steel could be so improved as to compare better as to strength with crucible steels, and the latter be also improved to the extent it appears to have been in our first tests, there would be opened for these alloys a large field of usefulness, and for these titaniferous ores a very important application.

In tests made in some establishments we have used simultaneously the titaniferous pig and the alloy in the cupola, and the results were such a toughness combined with a remarkable hardness and strength of chill in car-wheels that it has justified the statements of some manufacturers as to the importance of these products in the iron industry, when better known. To obtain them cheaply—and we mean by that at such a price that their use would prove economical in view of the results secured—has been our aim.

We may remark here, that if the thickness of a casting can be diminished without impairing its strength—on the contrary leaving it stronger—the cost of the material which has secured such a result may well be compensated for and more by the advantages obtained.

We are continuing our tests along these lines for different establishments, and we may be justified in saying, as a conclusion, that if these tests and those carried on by outside parties, to whom we are willing to extend all facilities to make them, justify our claim, as those already made have done, that the importance of the metallurgy of titanium cannot be ignored or overlooked much longer, and that these titaniferous ores, as we have said at the outset, will constitute a valuable resource and reserve for the future, both for blast-furnace stock for the manufacture of pig-iron and for metallurgy in general for the production of valuable alloys. Titanium may be found to form alloys with other metals than iron, or with iron and other metals possessing special

and valuable qualities. We have had no trouble, by following our aluminum method, in making alloys of titanium and copper and titanium-iron, and other metals, alloys of which we are now engaged in studying the properties, some of which appear to be rather remarkable.

NEW YORK, April, 1902.

RECENT PROGRESS IN ELECTROCHEMISTRY.

A novel method for the production of calcium carbide is suggested by MM. Vulitch and d'Orlowsky, of Paris, the authors proposing as an alternative to the usual practice of heating a suitable mixture of lime with carbon, to first fuse the lime in an arc furnace, and then discharge the molten mass into an excess of heavy hydrocarbon, such as "masud," or other residue of petroleum distillation. The formation of the carbide occurs within the body of hydrocarbon, and the product possesses, as would be expected, some distinctive properties: it is loose and non-coherent, and is saturated throughout its mass with the hydrocarbon, which modifies its relations with water, rendering it practically non-hygroscopic. It is peculiarly adapted for the intermittent generation of acetylene, since it is not penetrable by water, and the evolution of gas continues only during the period of actual immersion. It is asserted also that it is free from phosphorus, which is eliminated by forming with the hydrocarbon volatile hydrides.

In Hall's improvements in electric furnace methods for the purification of beauxite, as will be recalled, the silicon and titanium are separated by reduction, and are collected in iron, either normally present or added in proper quantity. An additional patent issued to Hall, under date of June 3, 1902, deals with the utilization of this alloy as a basis for a metallic paint. An alloy containing about 60 per cent. of iron and 40 per cent. of one or all of the electro-positive metals mentioned, is brittle and readily comminuted; mixed or ground with oil it constitutes the paint of the patent.

The colloidal condition assumed by many metals under special conditions of precipitation is clearly a problem for the electrochemist, and when fully elucidated will undoubtedly throw additional light upon the mechanics of solution. Such metals as gold, silver, platinum, tin and mercury may be readily obtained in a form soluble in water, but separated therefrom by evaporation, freezing, or the addition of electrolytes. Subjected to the electric current they separate upon the anode, or if a diaphragm be employed, upon its negative side. In common with other colloids they are incapable of penetrating a porous membrane, and their solutions may therefore be concentrated by dialysis.

Colloidal silver is well known through the classic work of M. Carey Lea; colloidal gold has been studied by Zsigmondy, who prepared it by the reducing action of aldehydes upon extremely dilute hot alkaline solutions of chloride of gold; and colloidal mercury has been prepared by Lottermoser by reduction by stannous chloride. Gold, silver, platinum, cadmium and zinc have also been obtained in this form by Bredig by the action of a luminous arc

between metal wires in an extremely dilute solution of caustic potash. Dr. Carl Paal, of the University of Erlangen, has now prepared both gold and silver not only as colloidal solutions, but as measurably pure metallic products. The gold exists as bright scales of bronzy luster containing over 70 per cent. of the metal, and the silver as lustrous blue scales of above 90 per cent. purity. Both metals readily and completely dissolve in water—the silver with a bright yellow-brown coloration and the gold to the intense red solution of Zsigmondy. Both metals are precipitated by dilute acids, but in sharp contradistinction to the forms heretofore obtained the precipitates readily dissolve again in weak alkali.

The colloidal gold is prepared by pouring the chloride in concentrated aqueous solution into a heated alkaline solution formed by the treatment of albumens with warm dilute alkali; the solution obtained is dialyzed against water, precipitated by dilute acetic acid, redissolved in dilute caustic soda, and the metal recovered by slow evaporation. Colloidal silver is prepared in a substantially similar manner.—*Clinton Paul Townsend in Electrical World.*

VIRTUES OF THE PINEAPPLE.

The partaking of a slice of pineapple after a meal is quite in accordance with physiological indications, since, though it may not be generally known, fresh pineapple juice contains a remarkably active digestive principle similar to pepsin. This principle has been termed "bromelin," and so powerful is its action upon proteids that it will digest as much as one thousand times its weight within a few hours. Its digestive activity varies in accordance with the kind of proteid to which it is subjected. Filbrin disappears entirely after a time. With the coagulated albumen of eggs the digestive process is slow, while with the albumen of meat its action seems first to produce a pulpy gelatinous mass, which, however, completely dissolves after a short time. When a slice of fresh pineapple is placed upon a raw beefsteak the surface of the steak becomes gradually gelatinous, owing to the digestive action of the enzyme of the juice.

Of course, it is well known that digestive agents exist also in other fruits, but when it is considered that an average sized pineapple will yield nearly two pints of juice, it will be seen that the digestive action of the whole fruit must be enormous. The activity of this peculiar digestive agent is destroyed in the cooked pineapple, but unless the pineapple is preserved by heat there is no reason why the tinned fruit should not retain the digestive power. The active digestive principle may be obtained from the juice by dissolving a large quantity of common salt in it, when a precipitate is obtained possessing the remarkable digestive power just described.

Unlike pepsin, the digestive principle of the pineapple will operate in an acid, neutral, or even alkaline medium, according to the kind of proteid to which it is presented. It may, therefore, be assumed that the pineapple enzyme would not only aid the work of digestion in the stomach, but would continue that action in the intestinal tract. Pineapple, it may be added, contains much indigestive matter of the nature of woody fiber, but it is quite possible that the decidedly digestive properties of the juice compensate for this fact.—*The Lancet.*

Mining and Metallurgical Section.

[*Joint meeting of the Section and the American Institute of Mining Engineers, held Wednesday, May 14, 1902, at the Manufacturers' Club, Philadelphia.*]

The Beaumont Oil Field, with Notes on Other Oil Fields of the Texas Region.

BY ROBERT T. HILL, Washington, D. C.

(*Concluded from p. 238.*)

THE GEOLOGY OF THE BEAUMONT FIELD.

The Coast Prairie is a belt of prairie land from ten to fifty miles wide which borders the Gulf of Mexico for nearly 400 miles from the Mississippi in Western Louisiana through Texas into Mexico. It is one of the newest made and least understood of our American geographic provinces.

This is a grass-covered constructional plain, newly reclaimed from the Gulf of Mexico. In general character it resembles very much the New Jersey flats of our northern coast, with which it has many features of age and mode of origin in common.

Topographically, it is an almost level plain, sloping seaward at the rate of about one foot to the mile; its interior margin rises scarcely 100 feet above the sea. It is impossible with present knowledge to delineate the interior border with exactness, for belts of timber constantly encroach upon it. Its almost level surface is broken by a few low drainage-grooves. There are deep drowned bayous in Louisiana and East Texas; but these become fewer and more faintly developed toward the Rio Grande.

No topographic surveys have ever been made of any portion of the Coast Prairie, and hence the slight irregularities of its contour are discernible only with difficulty. Until Captain Lucas's investigations, certain low elevations, which have since become the most important features of

the landscape, were hardly noticed. I allude to low swells or hills such as Spindle Top, which occur here and there, and now attract attention from their supposed relation to the occurrence of oil beneath them. These mounds or hills are in reality gentle swells.

Until the past decade this country, which is swampy in places and in its southwestern extension semi-arid, was considered good only for cattle-raising. For fifty years, immigration passed beyond it to the more fertile portions of the State. Prior to the recent oil boom, however, it was acquiring a great impetus through the development of rice-culture, and to-day it is one of the most active industrial sections of the Union.

Geology of the Coast Prairie.—The low relief of the Coast Prairie, the absence of extensive natural or artificial cuttings and the mantle of vegetation render difficult the study of the problems of its stratigraphy and structure. We know that this prairie is underlaid to an indefinite depth by a series of sea-muds and sands similar to the present marginal deposits of the Gulf. On a previous page I have given the geological series which should underlie the prairie, and called attention to the difficulty of classifying the later beds. These late Tertiary (Neocene) and Pleistocene formations which succeed the Frio clays of Kennedy (the top of the Angelina series), underlie the Coast Prairie, and contain the oil, have never been classified, and may be called the *X* beds until a definite classification is made. In addition to very recent alluvium and loam, they may include the formations described in Louisiana as the "Hudson" and "Grand Gulf." Paleontologists have also identified shells from the Galveston and Beaumont wells, which they have referred to the Miocene; but no geologist has ever identified formations of this age outcropping at the surface in the Texas series.

No proof has been obtained of the total thickness of the *X* beds nor the depth of the top of the Eocene Tertiary, beneath the Coast Prairie. In fact, not one of the drill-holes in the Coast Prairie, the deepest of which was the well at Galveston, Tex. (3,050 feet), has ever penetrated to it. Ac-

according to the section of this well, there are 2,920 feet of such strata beneath the Texas Coast Prairie of Recent, Pleistocene and Miocene Ages.

Some sections have been published which convey an idea of the material of the unconsolidated *X* beds. They are composed almost entirely of unconsolidated material, which weathers into a mantle of soil. One section at Beaumont shows the strata down to the oil-bearing rocks. Another, of the deep well at Galveston, Tex., includes the equivalents of all the strata passed through in the Beaumont well, together with 2,000 feet of lower, and probably from 100 to 3,000 feet of higher beds.

A third section is that of the Louisiana Petroleum and Coal Oil Company's well, 1,230 feet deep, in Calcasieu parish, on one of two small islands in the marsh which forms the head of the Bayou Choupique. The section originally given by Hilgard is republished in the "Geological Survey Report of Louisiana" for 1899, page 25.

A fourth section is that of the wells at Belle Isle, given in the "Louisiana Geological Survey Report," 1899, Plate XXII.

Some information concerning the formation of the Coast Prairie, with a *résumé* of previous work, is found in a preliminary report of the geology of Louisiana, transmitted in November, but without date of publication on the title page (probably 1900). On the map accompanying this report, it is remarked that the distribution of the post-Eocene deposits is based mainly on previous surveys.

A few fragmentary data concerning the character of the formation have been given by Dr. Loughridge in the special report on cotton production for the Ninth Census; but, as a whole, the Neocene, Pleistocene and Recent formations immediately underlying the Coast Prairie are still unstudied and uncorrelated.

Several of these sections would lead the reader to infer that the bottom of the *X* beds had been reached when the bodies of salt, sulphur and gypsum were encountered, and that these materials are of Cretaceous Age. Evidence will be presented later to show that this may not be the case.

According to a special report by Hilgard for the Louisiana Geological Survey, the Five Islands are the erosion-formed outliers of a cretaceous ridge or backbone which traverses Louisiana from its northwest corner in the direction of Vermilion Bay; and many geologists have referred the salt and sulphur beds to the Cretaceous.

A sifting of all the evidence upon the subject affords no proof of the Cretaceous Age of the salt islands, which has been asserted solely on lithologic grounds, paleontologic evidence being entirely lacking. It is true that there is a change of material in several of the drill-holes, as, for instance, from the salt of the salt island and Damon's Mound, and the dolomite of Big Hill; but if these materials have originated by secondary replacement, as I maintain may have happened, they may be of post-Tertiary Age.

Structure of the Coast Prairie.—The Coast Prairie is topographically monotonous and so near to sea level, and the geological formations so unconsolidated and indeterminate, that there are no surface factors to enable one to determine the elementary features of structural deformation, such as the anticlines and synclines, which are so easily traceable in other regions where indurated rocks abound. Notwithstanding its apparent simplicity, however, there are some knotty problems in the underground structure of the Coast Prairie which present a peculiar exception to all the rest of the Coastal Plain. As already observed, the outcrops of lower and lower beds occur in succession from the coast inward. But this is not true of the *N* beds. There is distinct evidence that among these, newer beds overlap older formations, which do not outcrop at the surface anywhere in the Coastal Plain. Thus, Miocene fossils have been recognized in the Galveston and Beaumont wells where no formations of this age are known to outcrop anywhere at the surface. The stratigraphic unconformities noted by Kennedy between the Camden and Angelina series, and the Angelina series and the *N* beds, also have an important bearing on this question.

There is some evidence that the Coast Prairie overlaps conceal a line of serious deformation, which may be a sharp

fold, with an increased dip coastward, or a zone of faulting. The normal dip of the Eocene strata immediately west of the Coastal Plain is from 10 to 20 feet per mile. If this rate of inclination continued to the coast, these strata would be buried only from 500 to 1,000 feet. But, as I have shown, they are probably more than 3,000 feet below the surface, showing either a rapid change in dip to 60 feet per mile, or a down-throw fault.

If such faulting or deformation exists beneath the Coast Prairie, overlapped and buried by later surface formations, the fact is most important. I shall recur to it later.

The Louisiana part of the prairie is acknowledged to be a subsiding area, as attested by actual bench-marks, the drowned character of the bayous, and the circle of cypress growth on the swamps. I know of no actual previous observations bearing upon the isostasy of the Texas portion of the prairie. McGee, in a recent article in the *National Geographic Magazine*, assumes that it is likewise subsiding; but observations made within the past year lead me to believe that west of the Trinity River, at least as far south as the mouth of the Colorado—beyond which we know nothing—the plain is rising. Between the Trinity and the Colorado all the streams have new-cut channels, characteristic of rising land, while the Brazos is actually cutting down through its own alluvium at sea-level, and for many miles above its mouth.

In the generally monotonous monoclinal structure there are a few wrinkles or small swells, likely to escape the eye of even the trained observer, and yet of a character which may have an important bearing on the oil-problem. These are the circular and oval mounds already described, which were first recognized by Captain Lucas. When he pointed out Spindle Top Hill to me, my eye could hardly detect it, for it rises by a gradual slope only 10 feet above the surrounding prairie plains. I was still more incredulous when he insisted that this mound, only 200 acres in extent, was an uplifted dome. But Captain Lucas said that I would be convinced of the uplift if I could see Damon's Mound in Brazoria County. In August, 1901, I visited that place, and

then returned for a second look at Spindle Top, and was convinced, that if these hills are not recent quaquaversal uplifts, no other known hypothesis will explain them.

Damon's Mound is an elliptical hill, a mile or more in greater diameter, rising 90 feet above the surrounding level. Its profile is everywhere convex, and it is not a hill of erosion or of volcanic material. Furthermore, a bed of limestone follows the contour of its surface, showing deformation. The ascent of the plain will not carry the latter to the height of this mound for 100 miles interiorward.

Phenomena Accompanying the Oil in the Beaumont Field.—By studies and drill-sections of the Coast Prairie, the following facts have been developed:

(1) The oil is closely associated with the mounds occurring on their slopes or summits.

(2) The mounds are usually anticlinal or quaquaversal in structure.

(3) Most of the chemical phenomena of the Lucas group occur in all these mounds in varying proportions.

(4) In some localities, hot water has been struck below the oil.

(5) In the original Lucas well, the oil itself is hot.

The oil seems to occur, not in any definite, continuous stratum, but in spots of many strata, under varying conditions. At several places, notably Rockland, Saratoga and Sour Lake, it is found at the surface as maltha or asphaltum, impregnating spots in beds of sand, which are indurated by it. At Jennings, Beaumont, Sour Lake, and other localities, several—at Sour Lake, for instance, eleven—"seeps" of oil have been encountered.

Gas in immense quantities, and frequently under such pressure as to wreck the wells, has been struck before reaching the oil. This has occurred several times at Spindle Top, twice at Sour Lake and once at Velasco, where the destructive effect was terrific.

Sulphur and sulphuretted hydrogen gas occurs in intimate association with the Beaumont oil. In fact, the oil itself is said to contain from 1 to 2 per cent. of sulphur, and the fumes of sulphuretted hydrogen are strong in the vicinity of the wells.

Captain Lucas early noticed that sulphuretted hydrogen, escaping from the earth under certain conditions, deposited sulphur in crevices near the surface. Such phenomena he observed at Spindle Top before commencing his well. At High Island, Galveston County, work was temporarily suspended on a well-hole, and the orifice was stopped with hay, in order to prevent obstruction from *débris*. Afterwards, when this plug was withdrawn, the hay was found to be imbedded in a matrix of sulphur, undoubtedly deposited from the escaping gas. At Damon's Mound, Brazoria County, sulphur was found near the surface only in small joints and fissures; and a clay impregnated with it, used as an ointment by the Indians who formerly inhabited the coast country, was subsequently mined and sold as a medicine by a company of Americans.

Underground bodies of sulphur, associated with the oil by natural processes, have been found in many localities. The Calcasieu section of Hilgard shows at 540 feet in depth solid "sulphur rock," similar to that encountered at 1,040, feet in the Beaumont well. At Damon's Mound a bed of sulphur from 10 to 40 feet thick was encountered above the salt. Crystal of free sulphur also occur in a cap-rock overlying the Spindle Top oil.

The following is reported of the well bored by Boughton & Wynn for the Higgins Oil Company at Spindle Top. I cannot vouch for the correctness of the statement:

"The drillers claim that the oil-pool struck by their well is 40 feet deep, and that the oil rests upon a bed of sulphur. After the oil was struck, the borers permitted the pipe to sink until it struck bottom, which it did at the distance of 40 feet. The drillers then claim to have bored 4 feet into a bed of pure sulphur."

This well is about 800 feet from the Lucas well.

The bodies of sulphur are probably a by-product of the formation of the oil, which, at Spindle Top, is not only highly saturated with sulphuretted hydrogen, but contains by chemical analysis from 1.5 to 3 per cent. of sulphur. It was Captain Lucas who discovered the relation between the sulphuretted hydrogen fumaroles, gas-springs and sulphur incrustations at the surface, and the bodies of subterranean

oil; and it was his belief in this association that led him to seek for oil on Spindle Top Hill.

The bodies of salt discovered beneath the hills of the Coast Prairie are of remarkable size, thickness and purity—notably those in Louisiana, and one discovered in within the past few months at Damon's Mound, in Brazoria County, Tex.

The salt islands of Louisiana were described by Captain Lucas in the *Transactions* of the American Institute of Mining Engineers before his discovery of oil at Beaumont.* These so-called islands, rising from 80 to 250 feet above the surrounding marshes of the Coast Prairie, are hills beneath layers of stratified clay and sand. They belong to the same group of topographic phenomena as Spindle Top Hill at Beaumont.

By sinking through the superstructure of sand and clay, Capt. Lucas located the salt-bodies and determined their horizontal extent, developing also the important fact that, though limited in diameter, they were of great depth—that of Jefferson Island having been penetrated for 2,100 feet without reaching bottom.

Another important fact pointed out in Capt. Lucas's paper was that the substrata of the southeastern part of Belle Isle, above and down to the rock-salt, were heavily impregnated with petroleum. Several calcareous strata containing sulphur were also encountered, suggesting to him that more thorough exploration might develop a sulphur-deposit like the great Calcasieu deposit, and showing the association of these three materials.

All geologists who have expressed an opinion have committed themselves to the theory that these salt-masses were originally deposited in the sea and covered with later sediments. Capt. Lucas also accepted this hypothesis. The theory as stated by Adams† was, that “near the close of the Cretaceous Period, beds of rock-salt and gypsum were evidently precipitated in the land-locked remnants of the retreating sea.”

**Trans. A. M. I. E.*, xxix, 452 et seq.

† U. S. “Geological Survey,” *Bulletin* No. 184, p. 49.

The sediments of the lagoons, which in former times, as to day, bordered the Gulf of Mexico, were undoubtedly very saline; but we have no instances at present to lead us to suspect or believe that there have ever been conditions for the accumulation, by surface evaporation in such lagoons, of the enormous thickness of salt now found beneath the Coast Prairie mounds of Louisiana and Texas.

These vast salt-bodies are intimate historic associates of the oil, and record the past location of the circulation of saline waters, which were transporting agents in the distribution of the oil.

Since studying the phenomena of the Beaumont field, the writer has gradually developed another hypothesis, namely, that these salt bodies are the result of secondary replacement in the strata through the agency of the ascending circulation of saturated briny waters, as elsewhere explained.

Still another interesting phenomenon is the occurrence of dolomite. The oil of Spindle Top is said to occur in a cavernous mass of this material. At Big Hill, Jefferson County, which is one of the most conspicuous of the mounds, the drill, after going down 300 feet, penetrated a mass of solid, coarsely crystalline dolomite, in which it continued to nearly 1,375 feet. At 900 feet a small seep of oil was struck in the dolomite. This would suggest, at first glance, that a boss of ancient crystalline rock had been encountered; but such is probably not the case, as I shall endeavor to show.

In only one well, so far as I am able to ascertain, has the hot water which would be expected to follow the oil been encountered. This was in the Sour Lake field, where, as I am informed by the owner, a heavy flow of hot salt water was struck at about 1,400 feet—a lower level than that of the “gusher” oil of that vicinity.

The fact that the oil in the original Lucas gusher had a temperature of over 110° F. is most important. This phenomenon seems to have been overlooked heretofore by those who have studied the field.

Explorations have shown the following downward series in the quaquaversal hills: (1) a matrix or overlay of the

typical Coast Prairie formations; (2) oil-phenomena, consisting of sulphuretted hydrogen gas, escaping superficially, and secondary deposits of sulphur in the strata through which the sulphuretted gas has ascended; (3) oil, mixed with considerable sulphur and sulphuretted hydrogen; (4) sulphur, as a precipitate or sediment of the oil; (5) sodium chloride and magnesian lime carbonate, as after-products of the oil; and (6) hot salt water, under great hydrostatic pressure.

GEOLOGICAL SOURCE AND DISTRIBUTION OF THE OIL.

The ablest geological experts and practical oil-men have found the conditions in the Beaumont field different in every detail from those of all previously discovered fields, especially those of Ohio, California, West Virginia and Pennsylvania. The magnificent work of Orton, in Ohio; White, in Virginia, and Lesley and others in Pennsylvania, is inapplicable in this field.

The writer, like other geologists, assumed at first that oil-deposit was more or less of the sheet or blanket type, and for a while proceeded upon that theory, until it was upset by experiments around Spindle Top. A year ago I was inclined to believe that the Beaumont oil was, like that of the Trenton, Berea and Corsicana fields, indigenous to certain strata. But we are unable to define and describe such strata; and all evidence now tends to disprove that proposition.

While science has said, frankly, "We do not know, but we shall learn," fakirs of every imaginable kind and well-meaning practitioners from other fields have given advice in abundance. The man with the divining-switch; the boy who could see underground streams blindfold in the night; the electrical indicator man; the Pennsylvania oil-driller who recognized Pleistocene and Recent gravels on the surface as identical with the Paleozoic conglomerates of his native State, and a host of quack-geologists, have reaped a rich harvest in this field through the foolish and fruitless expenditure of much money.

Before the discovery at Spindle Top, there was only one

man whose ideas—although not yet co-ordinated into a theory—approximately fitted the observed conditions. Of course I refer to Captain Lucas, who, in his explorations of the Coastal Plain, seeking successively salt, sulphur and oil, had observed the association of oil, sulphur, sulphuretted hydrogen gas, gypsum, dolomite and salt, constituting collectively what might be termed the oil-phenomena, representing a group of secondary products, as distinguished from the mother-strata or sediments out of which they had been produced. Moreover, so far as I am aware, he first pointed out the existence of anticlinal hills in the Coast Prairie and their connection with the oil-phenomena. Concerning the origin and geology of the oil, however, he presented no opinions.

Captain Lucas also attached much significance to certain surface-phenomena, indicating that the sulphuretted hydrogen, escaping upward, either acidulated the surface-waters or deposited incrustations of sulphur in the soil. He inclined to believe that the mounds themselves were in some manner the result of the gas-pressure; and I think he favored the notion of horizontal distribution along lines of strike.

AN EXPLANATORY HYPOTHESIS.

The writer has in mind an hypothesis, not hitherto advanced, so far as he is aware, which co-ordinates Captain Lucas' data and explains that which he omitted—the source and distribution of the oil salt islands, sulphur, sulphuretted hydrogen gas, and dolomite. The hypothesis is offered with hesitation, not as a final explanation, but in the hope that it may serve as a basis for discussion through which the truth may be reached. I think it fully interprets the Lucas group of phenomena, and accounts for the mystery of Spindle Top far more satisfactorily than any other thus far presented; and that it may also account for the independent origin of the sulphur, sulphuretted hydrogen and gypsum, regardless of their association with the oil.

The hypothesis is as follows: The oil- and salt-pockets of the Texas Coastal Plain are probably not indigenous to the

strata in which they are found, but are the resultant products of columns of hot saline waters which have ascended, under hydrostatic pressure, at points along lines of structural weakness, through thousands of feet of shale, sand, and marine littoral sediments of the Coastal Plain section, through which oil and sand are disseminated in more or less minute quantities. The oil, with sulphur, may have been floated upward on these waters, and the salt and dolomite may have been crystallized from the saturated solution.

The channels of these ascending waters may have been in places of structural weakness, such as fissures, which probably at one time continued to the surface, but may have been sealed by the deposition of the later overlapping strata now capping the oil-pools. Such features, when occurring under gentle anticlines, may explain the collection of oil beneath the surface in pools.

The following known data may be adduced in support of this hypothesis: (1) The absence, at the depth of the Beaumont wells, of any local sheet or stratum from which it is probable that the tremendous body of oil could have been generated; (2) the probable existence of nearly 10,000 feet of Cretaceous, Tertiary, Quaternary and Recent unconsolidated sediments beneath the surface of the Coastal Plain, as demonstrated by the deep well at Galveston, and studies of the outcrops farther inland; (3) the dip of these strata beneath the Coast Prairie at a low angle, from the interior coastward; (4) the oil disseminated in small quantities in many of these strata; (5) the existence of seven or eight distinct reservoirs of artesian water in this series of strata, at depths which increase coastward; (6) the fact, demonstrated by artesian wells, that the water becomes hotter and more saline with increasing depth, thereby increasing its capacity for the collection and flotation of oil; (7) the intense hydrostatic pressure in these water-bearing strata, which apparently continue beneath the Coastal Plain; (8) the fact that this water has risen in spots along lines of fissure which are probably later, and are capped by 1,000 feet or more of the still later strata of the Coastal Prairie.

The evidence of these statements is as follows: (1) Experiments at Spindle Top, Saratoga, Jennings, Sour Lake and Velasco show that the accumulations of oil sufficient to produce gushers are not indigenous to the particular stratum in which they are found, but have been collected there as a result of other causes. It is also certain that the oil occurs in underground pools, which are related to the supposed anticlinal mounds in the new-made Recent Coast Prairie.

The main supply of oil at Spindle Top averages 1,000 feet in depth, and may be in strata of Pliocene or allied Miocene Age. But that this stratum in which the oil occurs is not continuously impregnated with a widespread sheet is testified by the barren ground developed all around Spindle Top. Nor do the many drill-holes bored up to this date reveal even any formation in the upper portion of the Coastal Plain capable of generating the vast quantity of oil found at Spindle Top, whatever its origin. These oils are not associated with extensive beds of either plant or animal remains from which the oil might have been generated. At one place, Saratoga, where they outcrop, they apparently occur in ferruginous sands.

A faint trace of oil is usually encountered at from 400 to 600 feet in depth, throughout the entire three hundred miles from Damon's Mound to Jennings. This was probably the first "seep" oil struck at about 600 or 700 feet in the Lucas well, and has been encountered at many other places. It may be a local horizon; but it has not been found to be always underlaid by a great "gusher" stratum, or by any signs of such a thing. That there are shallow strata beneath the Coastal Plain which are oil-bearing is apparent; but the product of all of these put together would not supply one "gusher."

(2) The now classical section of the deep well at Galveston, only a short distance from Beaumont, shows that there are at least 3,000 feet of unconsolidated gulf littoral sediments of later age than the Eocene Tertiary.

Beneath this there is every reason to believe (from its outcrop to the westward and dip toward the Gulf Prairie) that there must be an additional 300 feet of Eocene Tertiary

sands and clays. Similarly, west of the Tertiary, and dipping beneath it, geologists have measured at least 4,000 feet of marine Cretaceous formations, also dipping directly beneath the Coastal Plain.

If all these strata do (and no evidence has been as yet presented to show that they do not) extend beneath the Coast Prairie, then we have beneath it at least 10,000 feet of Cretaceous and later sediments, known to be (with the exception of 1,000 feet of consolidated limestones) almost entirely composed of more or less littoral, terrigenous, bituminous and ferruginous clay and sand.

(3) The dip of the buried portion of the strata of the Cretaceous and Eocene series beneath the present Coast Prairie is evident from the minute studies of the outcrops of these strata toward the interior. The Cretaceous strata dip toward the Coast Prairie from 25 to 40 feet per mile, as shown with great minuteness in the author's monograph of the Cretaceous formations.* The dips of the Eocene Tertiary, from 30 to 10 feet per mile, are given in the various reports of the Texas Surveys. While no one can say positively that these strata are beneath the Coast Prairie, induction leads to no other conclusion, and absolutely no reason can be advanced to prove that they are not.

(4) Of the 22,000 feet of sedimentaries in the Texas section, all but less than 2,000 feet are unconsolidated clays and sands, which may be more or less bituminous. Some of the limestones are also bituminous. Oil or bitumen has been found in at least a dozen horizons of the section. The older or Paleozoic group contains one in the Ordovician, and two or three in the Carboniferous (as at Brownwood, and at Henrietta, in Indian Territory). Of the strata composing the later grand group underlying the Coastal Plain, there are five oil horizons in the Cretaceous: one in the base of the lower Cretaceous (at St. Jo and Burnet); one in the Del Rio clays at Austin; one in the Eagle Ford clays in Grayson County; two in the Navarro beds of Corsicana; several in

* "Twenty-first Annual Report of the Director of the U. S. Geological Survey," Part VII.

the Eocene—notably that at Nacogdoches—and several in the post-Eocene at Beaumont.

In two instances, in Texas, bituminous matter (asphaltum) is found in apparently indigenous beds of limeshell conglomerate. One of these is the shell-breccia bed of the Travis Peak formation at Port Mountain, in Burnet County; the other is the shell-breccia in the upper Cretaceous at Cline, from which the Uvalde asphaltum is obtained.

The oil of the Corsicana field and that of San Antonio is derived from the shales of the Upper Cretaceous. The same strata which produce oil at Corsicana would, if continued, probably be embedded at least 4,000 or 5,000 feet beneath Beaumont.

The strata of the Eocene Tertiary present every favorable condition for the generation of petroleum, whether this material be derived from the decomposition of marine organisms, as alleged by some, or from the hydro-carbons generated by vegetable matter, as believed by others. There are vast accumulations of both materials in Eastern Texas.

It is an interesting fact that asphalts and oils rich in asphaltum occur in terrigenous (land-derived) sediments of the nature, age and general character of the East Texas Eocene, around the entire perimeter of the Gulf of Mexico and the Caribbean Sea. The asphalts of Tamaulipas in Mexico, Vera Cruz, the Isthmus of Panama and Cuba, as well as the great asphalt-deposits of Trinidad, Barbados and Venezuela, all come from beds of this character.

The oil from the Nacogdoches well is derived from near the top of the lignitic formations (Claiborne beds) of the Eocene Tertiary, the position of which has been definitely ascertained by geological study.

The X beds (post-Eocene) of the Coast Prairie are apparently rich in oily spots.

If a drill-hole could be continued to a depth of 10,000 feet below Beaumont, it should encounter: First, the Nacogdoches oil-stratum; next, the bituminous shales of the Eocene; next, the oil-shales of the Corsicana field; next, the Eagle Ford (Colorado) bituminous shales; then the bituminous beds which furnish the asphaltum of St. Jo and Burnet;

and, finally, the oil-shales of the Carboniferous. None of these strata were encountered within 3,000 feet of the surface in the deep wells at Galveston, or in any of the wells of the Coastal Plain. Between the Eocene or Claiborne stratum of Nacogdoches and the uppermost Pleistocene stratum of Beaumont there are thousands of feet of gypsiferous clays and sands in which nature may now be distilling oil.

(5) That the strata dipping beneath the Coast Prairie contain many beds (reservoirs) of artesian water is proved by extensive records and observations. These horizons are fully described in the writer's paper on the "Underground Waters of the Black and Grand Prairie."*

(6) This water increases in temperature with depth and in its capacity for taking in solution the solvent salts, and for upward flotation of the oil gathered in particles from the various strata through which it passes in greatest quantity. The fact that the water increases in temperature and salinity is conclusively proved by a line of wells, 100 miles in length, between Comanche and Marlin, in the lower portion of the Cretaceous series. The same stratum which furnishes water at both places outcrops at Comanche and supplies good potable water at almost every atmospheric temperature. At Marlin, 100 miles eastward, this water comes from a depth of 3,200 feet, has a temperature of nearly 140° F., and is excessively saline and sulphurous. Should the rate continue from Marlin to Galveston, this stratum would be, at the latter place, nearly 1,000 feet below the surface, and intensely heated and saline.

(7) If the lowest water sands of the Cretaceous of Texas are embedded beneath the Coastal Plain, several thousand feet below their outcrop, they must be under tremendous hydrostatic pressure. Their water must ever pass upward, and would take advantage of any structural weakness in the overlying beds to do so.

(8) In the discussion of the geology of the Coast Prairie, I have given some evidence of the existence of a strong monoclinal fold or faulting beneath the Coast Prairie.

* Twenty-first Annual Report of the U. S. Geological Survey, Part VII, Washington, D. C., 1902.

There is much evidence that the present and former Coastal Plains of Texas, marking the recedence of the old shore-line of the Gulf of Mexico from the Rocky Mountain Region to its present site, has experienced periods of pause, producing a series of concentric shore-lines, accompanied by faulting. It is a singular fact that in another part of Texas, adjacent to a region which was at one time a coast-line of the Gulf of Mexico, there existed such a line of weakness. The great Balcones fault, which the writer has frequently described, is of this character. It is very probable that, along the present coast-line, similar faulting took place in Eocene time, and that the evidence thereof has been obscured by overlapping of the Grand Gulf and later formations which veil the Coast Prairie.

It is also true that there are unconformities in the coastal section, such as the one described by Kennedy, which might have overlaid such fault-fissures in the Coast Prairie with more recent deposits.

If these deeply embedded water-bearing strata under tremendous hydrostatic head exist beneath the Coast Prairie, their waters would pass through any natural channels, such as fault-fissures, through all of the known sheet-oil horizons of Texas, except those of the Carboniferous formation. Such hot water would gather from the rocks, which are known to contain them, oil, salt, lime, sulphur and gypsum; and the oil gathered from these strata would be floated on the ascending saline waters.

If ascending columns of oil and water of this character should meet resistance near the surface, we could well conceive of the formation of such a pool as that beneath Spindle Top Hill. To produce such a formation, which would be practically like the end of a "mushroom" bullet, there must be resistance; and this resistance would naturally come from an impervious formation. The overlap of the upper *X* beds of the Coast Prairie, stopping the free exit of the water upward through the fault-lines, would produce such a resistance; and this overlap we believe to have taken place.

At any rate, should such a column of ascending water

with oil on top of it, reach a resistance near the surface, a subterranean pool of oil would result, such as we find at Spindle Top. Furthermore, the reaction which would take place in the column of water below the oil could theoretically account for all of the after-phenomena of the Coast Prairie mounds, such as the salt islands of Louisiana and Damon's Mound, and the dolomite of Big Hill.

It is a remarkably interesting fact that in the mammoth artesian springs of the Balcones fault-zone, between Austin and Del Rio, we have an analogous group of data showing the rise of subterranean water in spots along a line of faulting. Along this line great columns of water are now rising, not continuously, but in spots, like the supposed ancient artesian springs of the Coast Prairie. I allude to the series of springs at Austin, San Marcos, New Braunfels, San Antonio, Fort Clark and Del Rio.*

It is true that these waters do not bring any perceptible oil to the surface; but this is easily explained, since they pass mostly through limestones and non-bituminous strata. On the other hand, had they been, as the old structure of the Coast Prairie has been, overlapped by more recent formations, they would constitute columns of suppressed water like those we have theoretically supposed beneath the Coast Prairie.

A remarkable discovery has been made within the past few weeks, indicating the correctness, from a scientific point of view, of Captain Lucas' theory that the mounds were the *loci* of his groups of oil-phenomena, and supporting the hypothesis of ascending waters. In Brazoria County, Texas, some 350 miles west of Belle Island, Louisiana (almost as far as Philadelphia from Cleveland), the lonely mound known as Damon's Mound, similar to those of the Louisiana salt islands, rises out of the prairie. This has been penetrated, and proved to be an anticlinal dome similar to that of Belle Isle, with a similar stratigraphic section: Pleistocene sand and clay, with traces of sulphur in the surface-layers; oil;

* See "Geology and Underground Waters of the Edwards Plateau," 18th Ann. Rep. U. S. Geol. Surv., Part II.

then sulphur; and, for its lower 700 feet, pure rock-salt, with occasional traces of oil, demonstrating the occurrence of the latter substance, but not in commercial quantities.

Now, the question arises, is Damon's Mound a fossil-oil hill, beneath which the oil existed but has passed away? If so, why not also the Five Islands, and other salt islands of Louisiana?

FOOD VALUE OF THE MUSHROOM.

The *London Lancet* says: "The notion has long been held that the mushroom presented the composition of animal flesh, which led to its being called the 'vegetable beefsteak.' It appears, however, that this conclusion has been based on some analysis made many years ago, when analytical methods were not so exact as they are now and when the chemistry of food was not so well understood. In one regard, at any rate, the mushroom does resemble a beefsteak—in that it contains practically the same amount of water. But the dry, solid constituents of the mushroom differ very materially in kind from the solids of meat. The most important difference is due to the rich proportion of proteids—the so-called flesh-formers—in meat as compared with the feeble amount in the mushroom. This fact, as ascertained by recent analyses, hardly justifies the mushroom being regarded as a 'vegetable beefsteak.' It may be a blow to the vegetarian, but he would have to consume at least ten pounds of mushrooms in order to gain the equivalent of a little over one pound of prime beef. Indeed, in the light of modern inquiry, there seems to be no reason for believing that mushrooms possess any greater food value than other ordinary fresh vegetable foods, and in many respects they compare unfavorably with them.

"Still, the fresh, tender mushroom is undoubtedly easily digestible, and as it contains carbohydrates, in addition to some proteid, it is obvious that it is of some dietetic value. This value is not comparable with that possessed by essential foods, such as meat, milk and eggs. The mushroom, however, contains an unusual proportion of potassium salts. Few will deny that the mushroom is an excellent adjunct to many dishes; it has an appetizing flavor, and this quality alone makes it dietetically valuable."

DANGERS FROM ELECTRICAL RAILWAY APPLIANCE.

George Westinghouse has pointed out certain dangers which, in his opinion, should be guarded against in the fitting of trains with electrical apparatus. Mr. Westinghouse says: "It is not very apparent how these dangers can be guarded against. A lifelong experience, however, in connection with safety appliances upon railroads has caused me to view the subject from quite a different standpoint from that usually taken, especially by inventors and promoters, and in some cases by manufacturers of electrical apparatus, who evidently dislike to emphasize the dangers attending the application of so much electrical machinery beneath the ordinary combustible

cars now generally in use and the utilization of which has been contemplated in order to keep down the total cost of installation.

"I believe a further useful purpose will be served by particularizing some of the dangers to be guarded against in the fitting of trains with electrical apparatus:

"(1) A great advantage of electric traction is the possibility of a much higher speed. This, however, while not extending the vision of the engineer in charge of the apparatus, will require a greater distance within which to stop the train.

"(2) When many tons of electrical apparatus are distributed beneath several cars of a train, and of necessity more or less loosely supported, and between which and the rails and roadbed there is but a small clearance, it is evident that much greater precautions will have to be taken than is ordinarily the case with the running gear of the present steamcars, derangements in which have often been the cause of accident.

"(3) Electrical apparatus supported beneath the car can develop, by means of a short circuit, heat-energy sufficient to instantly ignite cars of wood construction, and this has occurred repeatedly, notwithstanding the presence of safety appliances, intended to guard against such occurrences.

"(4) When a total wreck results from an accident (and experience has shown that accidents are inevitable, whatever the mode of propulsion) the debris scattered over the 'live' and other rails would render useless the ordinary circuit-controlling devices which may be located upon the cars. This emphasizes the importance of a non-combustible construction of cars."

A NEW INCANDESCENT ELECTRIC LAMP.

Osmium has the highest melting-point of any metal, viz., about 2,600° C., and it can therefore be used at a higher temperature than carbon in an incandescent lamp, making the efficiency correspondingly higher. The lamp was the invention of Dr. Auer von Welsbach, and the Auer Company, who are making it, will shortly be letting out lamps on hire. Owing to the rarity of osmium, it is found worth while to employ the metal remaining in the filaments after they have burned out. The chief difficulty appears to be the low resistivity of osmium. Owing to this, up to the present, lamps of 25, 35 and 50 volts only have been produced, and the smallest candlepower of a 35-volt lamp has so far been 40. The lecturer described experiments made with a 20-volt lamp at different pressures. At 20·5 volts the lamp gave 22 candle-power, and required 1·48 watts per candle. At 25 volts the efficiency rose to 0·99 watts per candle and the candle power to 46. At 30 volts the figures were 0·654 watts per candle and 99 candle-power; at 35 volts 0·487 watts per candle and 171 candle-power; at 40 volts 0·38 watts per candle and 275 candle-power; and at 50 volts 0·32 watts per candle and 460 candle-power. At this pressure the lamp burned out. A life-test was made on another lamp at its normal pressure. This lamp required 1·5 watts per candle at the commencement, dropped gradually to 1·36 and 1·32 watts per candle, and finished at 1·4 watts per candle after 1,100 hours. During this time the candle-power, which started at 14·7, rose gradually to 16·8 after 250 hours, and then dropped to 15 candle-power after 1,000 hours' use.—*Scientific American*.

CHEMICAL SECTION.

Stated Meeting, held Thursday, May 22, 1902.

A Review of Some of the Recent Literature of the Periodic Law.

BY ROBERT HART BRADBURY,
Member of the Institute.

(1) The test of a generalization comes when research multiplies the number of facts which fall within its scope. If these new facts can be correlated by the hypothesis they will lift it to a higher level of authority and scientific utility. If not, various things may happen. If the data which cannot be explained by it are not numerous, a hypothesis may be retained unaltered for a long time, and the facts which do not fall into line be ranked as exceptions. Rigorously speaking, this is an illogical attitude, for a scientific law admits of no exceptions, but it is justified by practical reasons. It is often imprudent to discard one generalization until another is at hand which shall serve as well, or better, to arrange the data and point out the direction of further advance into the unknown. Again, further investigation sometimes shows that, after all, the supposed disagreement is unreal and that this hypothesis which has been questioned is still able to serve as a basis for the arrangement of all the data in its field.

The recent revival of interest in the inorganic side of chemical science has subjected the periodic law to a severe test. Data have accumulated with great rapidity and have produced divergent opinions with respect to the possibility of explaining them upon the basis of Mendelejeff's system. Even the advisability of retaining the latter at all has been questioned. It is the purpose of this paper to give an account of some phases of this discussion.

(2) *The Place of Hydrogen.*—Considering the importance of the element and the obviousness of the problem, the place of hydrogen in the periodic system has been the subject of surprisingly little discussion. As a rule, the books

content themselves with simply leaving it out of the table, or placing it by itself somewhere in the margin, and fail to face the problem at all. Nevertheless, the problem is a real one. Hydrogen is an element of a very peculiar physical and chemical character, and it must belong somewhere. But the task of placing it is by no means easy.

The field is narrowed at the outset by the *univalence* of the element.* The valence of most elements has been a theme of discussion—that of hydrogen, never. Not only is it constantly univalent itself, but it appears able to impose the attribute of constant valence on other elements, for variable valence toward hydrogen is unknown. Hence, there are only two possibilities. Hydrogen must belong in group I, at the head of the alkali metals, or in group VII, at the head of the halogens.

For the following reasons the head of group VII appears to be the more suitable position:

(1) The hydrogen molecule is diatomic, like F_2 , O_2 , B_2 and I_2 . On the other hand Li, Na, R, Rb and Cs, like the other metals, form *monatomic* molecules.

(2) The numerical values of the atomic weights point to that conclusion. The difference between the atomic weights of consecutive members of the same vertical group is 15–20. Now $F-H=18$, which is entirely normal. But $Li-H=6$, which is unprecedented. Again, it will be shown hereafter that helium ($He=4$) must be placed in group VII. If, then, hydrogen is to be placed at the head of group I, there must be six elements whose atomic weights vary by such small increments that they can be inserted between $H=1$ and $He=4$. This is utterly anomalous, since the differences between elements horizontally consecutive are from .5 to 3.

(3) The gaseous character and low boiling-point of hydrogen are precisely what we should expect of a lower homologue of fluorine, since, with the halogens, volatility increases with decreasing atomic weight. But from cæsium to lithium, melting-point and boiling-point rise and vola-

* Masson: *Chemical News*, **80**, 283.

tility decreases with decreasing atomic weight, so that we should expect a lower homologue of lithium to be more difficult to melt and to vaporize than lithium itself.

(4) The transparent non-metallic character of liquid hydrogen is a powerful objection to placing it in the lithium group. But with the halogens, color becomes paler with decreasing atomic weight and there is no objection to assigning to a colorless element the position of a lower homologue of fluorine.

(5) Lithium unites with hydrogen with well-marked combustion (Guntz). Such behavior from a metallic vapor toward another metal of the same group would be extraordinary. But from a halogen it would be normal.

(6) The similarity in the formulas of acids and salts, and the existence of positively charged hydrogen ions in solutions is an argument for classing hydrogen with the alkaline metals. However, acids are sharply distinguished from salts by marked peculiarities of chemical conduct. Chlorine and the other halogens substitute hydrogen in organic compounds without essentially altering the nature of the substance, and this is an equally strong reason for classing hydrogen with the halogens.

In spite of all that has been said it must be admitted that the place in Group VII is by no means satisfactory. The energetic union of hydrogen with fluorine is not at all what we should expect from two consecutive elements of the same group, though not entirely without analogy (oxygen and sulphur). The chemical conduct of hydrogen is not that of a halogen. And since chemical energy and non-metallic character increase greatly from iodine to fluorine we should expect hydrogen to be a still more violent non-metal than the latter, which, of course, is very far from being the case.

(3) *The Place of Argon, Helium and the Allied Elements.*—Upon the discovery of argon and helium, discussion of their relations to the periodic table arose at once. For a time it seemed that the table offered no place for them, and many thought that it ought to be abandoned or profoundly modified on that account. Some, taking the other horn of the

dilemma, held fast to the table and questioned the elementary character of argon, speculating about the possibility of its being an allotropic form of some known element (nitrogen) of a mixture of two or more species of monatomic molecules giving an *average* atomic weight of about 40. Still others adopted the very sensible suggestion of Piccini that these elements might, at least for the present, be left out of the table altogether. For to place an element in any part of the periodic table is to make certain more or less definite statements about its atomic weight, valence and chemical character generally. It is difficult to do this with elements which have no valence and no chemical character. It is even possible to question the propriety of speaking of the "atomic weight" of an element like argon. For the atomic weight is a chemical constant, determined by chemical methods, and the use of such methods is impossible with an element which forms no compounds.

Ramsay* came to the conclusion that there is a place for elements of zero valence in Group VIII, where they can serve as linking elements between the halogens and the alkalis. But if this is the case, there must be a whole vertical group of such elements, and this group should display similar numerical relations to the other groups. The search for such relations led to the discovery of three additional elements of the group.

The differences between the atomic weights of consecutive elements of the same vertical group is 16 to 20. Thus $\text{Ce} - \text{F} = 16.5$, $\text{S} - \text{O} = 16$. Further down in the table we have $\text{Mn} - \text{Cl} = 19.5$, $\text{Cr} - \text{S} = 20.3$, etc. Now $\text{Ar} - \text{He} = 36$, just as $\text{Cr} - \text{O} = 36.3$ and $\text{Ti} - \text{C} = 36$. Hence there should be an element between helium and argon, whose atomic weight should be about $\text{He} + 16 = 20$. If the molecules of this element are monatomic, its density should be 10.

After a long and laborious search, Ramsay finally discovered the missing element in the gases obtained by the fractionation of liquid air, and gave it the name of *neon*. At the same time he discovered two other gases—krypton

* "Nature," 65, 161.

and xenon—which also turned out to be missing members of Group VIII.

The following little table will illustrate the function of these elements in the periodic system, and will show that they form a group whose numerical relations are very much the same as those of the other groups:

Group VII.	Group VIII.	Group I.
H (1)	He (4)	Li (7)
F (19)	Ne (20)	Nr (23)
Cl (35·5)	Ar (40)	K (39)
Br (80)	Kr (82)	Rb (85)
I (127)	X (128)	Cs (133)

It will be seen that these elements of zero valence and no chemical character form a natural passage from the strongly electro-negative non-metallic halogens to the strongly electropositive metals of the alkalis. It should be pointed out that this addition to Group VIII does not disturb the metals which have previously occupied that group. They still remain, exercising their linking function between the two halves of the long periods. This is a different function from that of helium and its allies, and therefore the great differences between these metals on the one hand and the helium gases on the other are not surprising. And besides, it is no new thing for elements profoundly different in chemical character to be placed in the same column of the periodic table. Witness the classing together of gold and cæsium, of manganese and fluorine, of chromium and oxygen.

The periodicity of valence finds clear expression in this classification of helium and its allies.* Thus:

The valence toward hydrogen	in Group IV	is 4
	in Group V	is 3
	in Group VI	is 2
	in Group VII	is 1
therefore, naturally,	in Group VIII	is 0

But the valence toward oxygen and electronegative elements	
generally	in Group IV is 4
	in Group III is 3
	in Group II is 2
	in Group I is 1
therefore, naturally,	in Group VIII is 0

* Howe: *Chem. News*, 80, 74.

(4) It will be noticed that the atomic weight of argon (40) is slightly higher than that of the element which follows it—potassium (39). This is a difficulty which is met with in at least two other cases. Almost all the atomic weight determinations of *tellurium* make it higher than that of iodine. The more cautious may still entertain doubts about the atomic weight of tellurium, and even of argon (on account of the impossibility of using chemical methods of purifying the element, or of furnishing chemical evidence of the fact of purity), but there is another instance, upon which there can hardly be any argument. If there is any truth in the transitional function of the triplets of metals in the eighth group, cobalt must precede nickel, thus—

Group VII.	Group VIII.	Group I.
Mn	Fe Co Ni	Cu

Yet the very accurate determinations of Richards leave no doubt that the atomic weight of cobalt (59) is higher than that of nickel (58.7). It is difficult to escape from the conclusion that an element may have a slightly higher atomic weight than one which follows it in the table. An interesting suggestion which Biltz has made upon this subject will be referred to below.

(5) This case of cobalt and nickel will serve to remind us of the fact that our conceptions of the transitional functions of the metals of the eighth group are more or less misty and unsatisfactory.* This is a matter in which precision of thought and statement are needed. For instance, iron, cobalt and nickel are transition elements between manganese and copper. Even if we restrict the statement to the free elements—which we have no right to do—there are difficulties; for instance, with respect to magnetic properties. But when we include the compounds in our field of view, it becomes exceedingly difficult to explain just what we mean by the transition.

Thus, since the group valence in the first group is 1, we should expect a transition or gradual variation in properties

* Locke : *American Chemical Journal*, 20, 581.

from univalent manganese to univalent copper. But univalence is unknown with manganese and also with the three transition elements. The transition must therefore be between bivalent manganese and bivalent copper. But bivalent manganese and copper have no place in the periodic system which requires Cu^I , Mn^I and Mn^{VII} .* Going back to the next element, chromium, we find Cr^{II} , which exhibits, in a sense, the group valence. If we accept that as a starting-point and stability as a criterion we have the following: Cr^{II} (unstable) — Mn^{II} (stable) — Fe^{II} (unstable) — $\{ \text{Co}^{II} - \text{Ni}^{II} - \text{Cu}^{II} \}$ stable.

It is impossible to describe this sort of variation as transition.

If we adhere to trivalent derivatives we are even worse off.

Cr^{III} (stable) — Mn^{III} (unstable) — Fe^{III} (stable) — Co^{III} (unstable except in double salts) — Ni^{III} (almost unknown) — Cu^{III} (non-existent).

However, in discussing transition, we must not lay too much weight on arbitrary conditions. The instability of chromous and ferrous derivations is due to the accidental presence of oxygen in the air, while the instability of many other substances is a matter of temperature. As Ostwald has somewhere remarked, we are often unfair in our demands upon the periodic law. It is a good deal to require of any generalization, that it shall correlate the vast mass of collected chemical data, and we must remember in what an unsymmetrical way the data are grouped, especially with regard to temperature.

Thus, while we have an immense amount of qualitative and some quantitative knowledge of the behavior of various substances through a narrow range of temperature, yet our knowledge of their behavior at high and low temperatures is wonderfully fragmentary. It is altogether likely that if our knowledge was more complete we should have less difficulty in constructing a satisfactory generalization. Meanwhile, the fact of qualitative and, to some extent, quantita-

* The Roman numerals denote the valence of the element.

tive variation of properties with atomic weight is beyond discussion, and one of the obscurest problems of the table—the position of the inert gases—has been completely solved. With increasing activity in the inorganic field, and especially further research of the rare elements, will come more light.

(6) Finally, reference may be made to a suggestion of Biltz.* This is nothing less revolutionary than to drop the tacit assumption that each place in the table can be occupied by but one element and to admit that certain places can be occupied by groups. In such groups the atomic weights are close together and the similarity of the elements to each other is very great. Thus, to occupy the place at present assigned to manganese in group VII, Biltz suggests a group which he calls Σ Fe and which includes manganese, iron, cobalt and nickel. Among other simplifications, this gets rid of the difficulty about the atomic weights of cobalt and nickel. Other summations in the seventh group are:

$$\Sigma \text{Pd} = \text{Ru Rb Pd}$$

$$\Sigma \text{Pt} = \text{Os Ir Pt.}$$

In group III, under indium, occur—

$$\Sigma \text{Ce} = \text{La Ce Pr Nd.}$$

Researches now in progress among the rare earths will probably make possible the formation of other groups. The adoption of Biltz's suggestion effects a distinct simplification of the system, though not so great as might be inferred from a casual inspection of his table. Biltz's paper is clearly and concisely put and is decidedly worth reading. It is not likely, however, that his idea offers a final solution of the problem.

CENTRAL MANUAL TRAINING SCHOOL,
DEPARTMENT OF CHEMISTRY, May 22, 1902.

* *Berichte*, **33**, 562.

The "Series-Vapor" and "Heat-Waste" Engines, as Supplementary to Single-Vapor Engines.

BY R. H. THURSTON,

Honorary Member of the Institute.

Progress in the evolution of thermodynamic systems of production of energy through the employment of the heat-motors has always been and always must be gained by application of certain definite and simple principles:

(1) The thermodynamic efficiency of the cycle employed must be made a maximum, and mechanical efficiency must be made as high as possible.

(2) Wastes must be minimized.

The thermodynamic efficiency of energy-conversion in the heat-engine in practice has always been and always must be improved by increasing the temperature-range of the cycle found to have best form for practical employment. In the steam-engine, this extension of that range is and always has been effected by raising the temperature, and incidentally the pressure, of boiler-steam. It has never been found practicable, as yet, to extend that range by depressing the lower limit of temperature of a diabatic expansion; hence great losses have been submitted to on that side of the temperature-range adopted on which most may be gained by a stated variation. It is more profitable to extend the range downward than upward, and neglect to so extend the lower portion of that range produced greater waste than similar loss of possible extension at the top. The waste-heat of the steam-engine is thus serious, and a "waste-heat engine" is more important than the imposition of higher temperatures and pressures, and of another cylinder in series to operate at the elevated pressure and temperature. In the gas-engine the upper limit is enormously elevated as compared with the steam-engine; but, unfortunately, the lower limit is also elevated and the various wastes increased; so that, as yet, the gas engine

fails to approximate its ideal even as closely as the steam-engine. It also needs to be supplemented with a "waste-heat" engine, and even more than any steam-engine.

The wastes, other than thermodynamic, are provided against by various expedients, more or less effective, which are constantly being improved upon, but which need not be here discussed further than to remark that the indications are that progress in their use seems to fully keep pace with that increased need which comes with increasing temperature ranges and improved thermodynamic efficiency.

"Possible improvements in the thermodynamic action of the steam-engine and its class of ideal heat-engines may occur in either of three principal ways:*

"(1) Improvements may be effected by change of type-cycle.

"(2) Improvements may occur through changes in the form of the cycle, without altering its distinctive characteristics.

"(3) Improvement may possibly be produced by change of working fluid.

"In illustration: Should it prove practicable to modify the operation of the steam-engine in such manner as, actually or in effect, to transform the second of the Rankine cycles—as produced in the regular working of the machine through the use of the steam jacket upon a metallic cylinder—into the first, that involving the use of a non-conducting cylinder, this change of cycle would usually, even in the thermodynamic case, effect a gain of above 10 per cent. Could still further improvement be made by converting the cycle, by change of construction of the machine, into that of Carnot, a further gain of 5 to 10 per cent. would be produced; these gains increasing with increasing ranges of pressure and temperature.

"Changes of the cycle itself may be of advantage when they involve increased temperature and pressure-range; when they insure more nearly adiabatic expansion; when they produce variations in the direction of approximating

* "Manual of the Steam-Engine," R. H. T.; Vol. I, p. 916, *et seq.*

better forms of cycle, as when compression, in the common cycle, is made to approximate the action of that part of the Carnot cycle, or when purely "cushion-steam" is reduced in quantity by reduction of clearance and 'dead spaces.'

"Changes of working fluid by substitution of ether, carbon disulphide, petroleum vapor, or other, for steam, have been seen to give in some cases special opportunity for securing increased efficiency by adapting the working substance to the desirable or practicable working range, for either temperature or pressure, while these advantages must be weighed against the usually unquestionably serious, sometimes obviously fatal, practical objections to their use, on the score of cost or of danger, or both.

"Multiple-fluid engines, of which the 'binary-vapor engine' is an example, are constructed with the object of extending the thermodynamic limits of adiabatic expansion and compression, and the intervening range of temperature, beyond those which are met with in a heat-engine in which a single working fluid is employed. The upper thermal limit is practically limited, in steam, by the impracticability of safely controlling the accompanying high-pressure, and, in fluids like air, by the difficulties of controlling temperature at perfectly controllable pressures. The upper limit of available pressure does not, in any known fluid, coincide with the higher limit of safe and available temperature. To secure the high values, thermodynamically and dynamically, of the measure of maximum efficiency $(T_1 - T_2)/T_1$, the range, $T_1 - T_2$ must be carried as high and as low as the environment of the machine will permit. This may be accomplished, in some cases, by the adoption of a working fluid which may be employed at the higher limit, and of another which may be used at the lower limit, rejecting the utilized heat of the one into the other, in such manner as to produce cycles in series, of which the adjacent thermal lines shall be coincident.

"In such engines the construction and arrangement of the working cylinder is the same, in general purpose and arrangement, as in a multiple-cylinder steam-engine of the compound or triple-expansion type; except that in the latter

a single working fluid is employed, with cycles in series, transferring the heat and its vehicle, the fluid itself, from cylinder to cylinder between the higher and lower limits; while, in the multiple-fluid engine, heat only is dropped, step by step, transferring it from one fluid to another, cylinder by cylinder. Thermodynamically, the multiple-cylinder and the multiple-fluid engines are identical. Since the gain of one degree in the range of temperature worked through has more value at the lower than at the higher limit, the introduction, at the lower limit, of working-fluids more volatile than steam, to utilize the rejected heat of the exhaust, now wasted in the atmosphere or the condenser, has especial interest for the engineer. It is further to be noted that, in the multiple-fluid engine, each cycle is necessarily isolated and its working fluid continuously circulated. Surface-condensation thus becomes an essential feature, and each condenser is a recipient of heat from the working cylinder next above in the series, and a source of heat for the element next in order. Each working fluid constitutes the source of heat-supply for its own cycle and the refrigerating fluid for that next above.

"A multiple-vapor series should evidently consist of fluids of which each will have a boiling-point under a good and manageable pressure, at or below the temperature of the condensation of the fluid next above it in series, and a good mean effective working pressure between that point and the temperature and pressure of its own condensation. The latter temperature should be that of the high-pressure boiling-point of the next lower substance in the series, or above it. The uppermost element of the series should have a manageable pressure at the lowest practicable temperature of vaporization. The lowest in the series should have a condensing point, or boiling point, somewhat above the temperature of the condensing water, and at that point its vapor should have the least useful pressure. If choice is further allowed, under the circumstances practically controlling the case, the series should have a fairly uniform distribution of the series of pressure-ranges, in order that a division of work as nearly as possible uniform among the

cylinders in series may give the desired work-distribution on the crank-pins of the engine."

"*Series Engines*" and "*Series-Vapor Engines*" are two classes of constructions which are thus denominated by the writer as distinguishing the two cases in which—as in the multiple-cylinder engine, illustrating the one class, the working fluid is worked in two or more cylinders, in series, as in the "heat-waste engine," illustrating the other class, series of working fluids are worked in a corresponding series of engines—a "cascade effect," as the French sometimes call it, is secured, through which, in the one case, the internal wastes of the engine are reduced by restriction of the expansion in a single cylinder and, in the other, the endeavor is made to secure a better adjustment of temperature and pressure-range to a common maximum; both being expedients to attain a higher thermal efficiency than can be obtained by the simple engine with its single fluid and in which the working fluid has an upper limit of temperature, which is fixed far below that which might otherwise be attained by the fact that its corresponding pressure has reached a limit due to danger, difficulty or cost of control; while its lower temperature limit is also restricted in value by the fact that the fluid, long before the limit is attained, reaches so low a tension as to be useless for thermodynamic action, the mechanical efficiency being thus made a vanishing quantity.

The "multiple-cylinder engine," or the "series engine" with the single fluid, does not modify this fact of an uneconomical adjustment of the temperature and pressure-limits of the single-fluid engine, although it does give great advantage, often, in permitting the extension of the process of thermodynamic transformation within the narrow range of practicable operation of the single fluid. The "series-vapor engine," on the other hand, enables some choice to be made among available working substances and in such manner as to permit at least crude adjustments of temperature and pressure-limits to a common and maximum working range, increasing the thermodynamic and the mechanical efficiency and their product, often, very greatly.

There are in all heat-engines two efficiencies, of the several in series between fuel and useful work, which are affected by this variation from the common type of machine. The efficiency of the machine as a heat-engine, its thermodynamic efficiency, is increased by any device which shall make it practicable to prolong the expansion of the working stroke throughout the full temperature-range between boiler and condenser, or to secure further approximation than is now commercially possible. The mechanical efficiency of the machine is improved by any device which may make the work of friction a smaller percentage of the total indicated work of the machine, thus enhancing the useful work and the total efficiency of the engine. Thermodynamic efficiency is promoted by increased ratio of expansion and mechanical efficiency is improved by any increase in the mean effective pressure of the working fluid at any stated ratio of expansion at any given temperature of the expanding fluid. There is no thermodynamic limit to expansion in the steam-engine, in the ideal case, short of the temperature and the vapor-pressure of the condenser; but there exists a commercial and practical limit at the point at which further expansion would return a gain, in value of increased power, less than the loss accompanying the gain, due to enhanced costs of production of that added power. The sources of this compensating loss are heat-transfer without performance of work and, outside the thermodynamic operation, excessive additional wastes by external conduction and radiation and added wastes of work through increase of the friction of engine by a necessary enlargement of the machine to accommodate the increased volume of the working fluid, while the mean effective pressure is diminished with similar result. When the mean effective pressure upon the piston approximates that which is required to move the engine without load, all power-production involves a waste of its full cost. When extension of thermodynamic range adds less value in work usefully available than it loses through increase of the heat-losses of the engine, further attempt to increase the thermodynamic efficiency produces a net loss to the full amount of outgo in the extension of the expansion-range.

If a fluid can be employed in a secondary heat-engine which is less subject to what is technically known as "cylinder condensation," and one which, at the temperatures of the lower range of pressure in the steam-engine during expansion, has a markedly higher vapor-pressure, it is evident that the new fluid would be available as an accessory to the primary working substance and its use would both reduce non-thermodynamic wastes of heat and, by increase of the mean effective pressure at the lower limit of temperature-range, save friction losses; thus both decreasing expenditures of heat and increasing the relative quantity of dynamic energy at the work-point.

There are some reasons for the belief that other substances are at once less subject to extra-thermodynamic wastes than is steam, and capable of furnishing comparatively high mean effective pressures at the low temperatures of the terminal portion of the expansion line. These fluids are practically available for use in the binary vapor-engine, and some have occasionally been thus employed.

The earliest writer to discuss this subject from the point of view of the modern engineer was probably Cotterill, who in his admirable treatise of the thermodynamics of the steam-engine calls attention to the fact that there exists an opportunity to utilize lower temperatures than those which fix the lower limit with the transformations of the steam-engine, and that this limit may be exceeded by the difference between it and the temperature of the condensing water, approximately; while the extended range offers a means of large gain. He further shows the advantage of replacing the condensing system in the steam-engine by a secondary engine in which a more volatile working fluid is employed, and thus pressures are rendered available at the same low temperatures which are in excess of the atmospheric pressure throughout the range of action of that element of the binary machine. This writer, the most original and sound student of the heat-engines of his date, states the desirability of adapting the working substance to the range of temperature through which the fluid is proposed to be worked, and indicates the necessity of employing gas-engines for tem-

peratures exceeding those now attained by the steam-engine, and volatile fluids for temperatures between those of the condenser of the steam-engine and of the condensing water, or even, probably, from the boiling point of water downward ; the use of the condensing system, with its liability to inward leakage of air, and the various other objections to its employment, being thus evaded in part or wholly. These fluids, however, necessarily involve the employment of a closed system, and this in turn compels the use of surface condensers and vaporizers, and of an equally essential system of pumps for transfer of the fluid from the lower to the higher pressures, these elements of construction often proving no less objectionable than the familiar condenser and air-pump and the circulating pump of the steam-engine.

The Fallacy of the Argument in favor of volatile liquids based upon their low "latent" heats is shown by computing the heat required to produce similar volumes of vapor with the various fluids from their liquids when having common initial temperatures. Thus, to produce a cubic meter of steam and of petroleum vapor employing a common mineral oil consisting of the hydrocarbons C_8H_{16} and C_8H_{18} , and at six atmospheres pressure would demand, respectively, 2,082 and 2,460 calories, while with alcohol the figure becomes 2,390.* Thermodynamically, all have similar efficiencies under similar thermodynamic conditions, and their relative values in practice depend, as elsewhere shown, upon the relations of temperature and of pressure-limits to each other and to pressures and temperatures external to the thermodynamic cycle ; while the relative sizes of engines and boilers required for any stated engine-power, the cleanness and convenience of use of the fluid, its costs and safety, all influence the choice, usually vastly more than thermodynamic relations. The special adaptation of the fluid in question in any case to the special use in view is the real matter for discussion and decision by the engineer, rather than any thermodynamic question, as a rule. Thus we find ammonia adapted for use where, in any special case, it is desirable to

* J. Heinz : *Abs. Proc. Brit. Inst. C. E.*, p. 56, 1902.

avoid the employment of a condenser. The petroleums may perhaps be found to excel in total efficiency in some cases, as notably with small powers, through their oily nature and non-conductivity, permitting reduction of internal waste by condensation in the working cylinder. Ether superheats during adiabatic expansion, and this may prove an advantage, practically, in the maintenance of adiabatic expansion in the cylinder, while its volatility makes it a promising secondary fluid in the binary engine; especially as, in common with all very volatile liquids, this volatility makes direct heating, as in the boiler, troublesome and sometimes possibly dangerous.

Cotterill, and also the writer, long ago recognized the fact that it may prove possible to find a secondary, if not a primary fluid, with the use of which the now serious loss by cylinder condensation in the steam-engine may be considerably reduced.

This author finally remarks: "Mr. Willans has shown that in a non-condensing engine, with a boiler-pressure of about 180 pounds, the consumption of steam need not exceed 18 pounds per horse-power per hour. Now, the range of temperature here little exceeds 150° , and is, therefore, no more than that between 212° and the average temperature of the atmosphere in our climate. Thermodynamic science tells us that, if properly utilized by a suitable working fluid, this is worth as much as the same range above 212° ; and it must, therefore, be practically possible to double the horse-power with the same consumption of steam, thus reducing the consumption to 9 pounds."

The question of utilizing the lower ranges of temperature now unavailable with the steam-engine is evidently no less important than the extension of the range upward. "All known engines are very imperfect in consequence of its neglect." *

Willans' figure for the non-condensing engine has since been reduced considerably and the condensing engine, with which, in fact, the series engine is properly compared, has

* Cotterill, p. 368.

made its record of about 10 pounds with moderately superheated steam, and the little quadruple-expansion engine of the Sibley College laboratories has, with pressures of 300 to 500 pounds, brought down the figure to about $9\frac{1}{2}$ pounds per horse-power hour. Utilization of the hitherto wasted temperature range should bring the record considerably lower still, perhaps to the limit anticipated by Josse, 6.5 to 7, for now usual boiler-pressures. This economy could only be attained, without the utilization of these low temperatures, by carrying the boiler-pressure upward, in utilization of a higher range, to 1,000 pounds or more. Combining the two movements should give about 5 pounds.

The Thermodynamic properties of this class of substances may have, in some cases, important bearing upon their availability as working fluids in heat-engines, whether simple or of the multiple-fluid class. The energy-distribution, where heat is supplied to such a substance in the cycle of the vapor-engine, is exhibited in the general equation of Rankine :

$$U = CJ[T_1 - T_2(I + \log. T_1 / T_2)] + (T_1 - T_2) / T_1 \cdot H_1 ;$$

where U measures the work of the cycle, C specific heat, J the value of the mechanical equivalent of heat (in British measures, 778), T_1 and T_2 the maximum and minimum temperatures of the cycle, and H_1 the latent heat of vaporization (in foot pounds, if in British measures) and at the higher temperature. The cycle here assumed is one taken as standard by Rankine and Clausius, in which no compression occurs but in which expansion is complete to the back-pressure at T_2 . This is similar to the cycle of the usual forms of vapor-engine; although, in the latter, expansion is seldom complete. This case and cycle will serve our purpose best.

In this expression, the second term of the second member measures the heat transformation, with complete compression, in the Carnot cycle. The first term of that member obviously measures the work gained by suppression of compression. The gain is, however, as obviously paid for by a more than proportional heat-supply, since the Carnot is the

most efficient of all cycles in use in the heat-engine of any class.

It is at once seen that the work of the cycle, up to the point of commencement of expansion, is performed by the latent heat, H_1 , of vaporization. The quantity of work which may be performed per unit of weight of the working fluid is thus largely dependent upon the magnitude of the quantity of energy stored in this form during the period of vaporization. It is further seen that the latent heat is transformed in this cycle with the highest possible efficiency; while the sensible heat, which finds expression in the remainder of the work-measure, is less efficiently utilized. It is thus evident that, other things equal, the larger the amount of vaporization of latent heat, and the more completely the cycle depends upon that store of energy for its work, the better the thermodynamic effect.

It is a matter of observation and experience, as well as of direct experimental determination, that the volatile fluids have small measures of latent heat of vaporization, and that the lower this value the more volatile the substance and the higher its pressure at a stated temperature of vaporization. A practically important fact results: that the volatile substance must be supplied in larger quantity per unit of work performed and the weight per horse-power hour increases with the diminution of this latent heat if the fluids compared are in other respects physically similar, the working cycle also being the same in kind. Water, the most common and least costly of working fluids, is thus that which stores most heat per pound and which requires the least quantity per unit of work performed.

Again, it is found that the volatile fluids, because of this lower storage capacity for heat, fluctuate most seriously with varying heat-supply at the furnace, and in some proportion to their volatility. They lack the large pressure-regulating power possessed by the water in the steam-boiler. The enormous fluctuation of pressure in the working cylinder of the engine in which the volatile substance is employed, as compared with such pressure-changes with water and steam, compels great precaution, in design-

ing both the engine and its boiler, to meet such possible dangers, and in operation. This danger is probably less where the vaporization is effected by the rejected heat of the primary engine than where produced by the direct heat of the fuel. Experience only can determine just how far this involves insurable risks.

The common, but perhaps not remarkable superstition among the ignorant, that all latent heat constitutes a waste and that this fact in itself gives volatile fluids thermodynamic advantage, has no foundation. In the steam-engine, for example, under usual conditions of good practice, this latent heat supplies by far the largest part of the work. On the other hand, the perfect gas, with its zero of such latent heat, may also be worked in the Carnot cycle with all the efficiency of substances having large vaporization latent heats. In this case, the utilized heat, however, is the *latent heat of isothermal expansion*; it is, after all, a latent heat. Latent heat, in either the one or the other of these forms, must be utilized to insure maximum efficiency of the cycle and highest possible economy in the engine, and the larger the proportion of latent heat so utilized the greater the work-effect per unit of cost and the better the heat-engine.

Clausius calls this latent heat "work-heat," since it is the measure of heat expended directly in the performance of the work of molecular displacement. It may be called "work-heat" very properly in another sense; it is the measure of the heat which is mainly the source of work by thermodynamic transformation. Thus, in the steam-engine, with steam at 75 pounds pressure, by gage, and a temperature of about 320° F., and with a condenser at 100°, the difference in sensible heat amounts to about 80,000 foot-pounds; but the latent heat of vaporization is the equivalent of about 650,000 foot-pounds, and the store of thermal energy is thus seen to exist mainly in the form of the potential energy of latent heat of vaporization, only about 12 per cent. of the total being in the form of sensible heat. Were the steam-engine, in this case, to utilize only the sensible heat, but to operate in the perfect-engine cycle of

Carnot, it would demand about 90 pounds of steam per horse-power hour; whereas, the actual engine of good standard practice is expected to call for not more than one-sixth that amount, the ideal engine of similar cycle demanding but about 8 pounds. (*Man. St. Engine*; Vol. I, p. 437.) The source of the energy of heat-transformation in the steam-engine is thus mainly the latent heat of vaporization, the rightly named "work-heat;" it provides about 90 per cent. of the total.

The quantity of heat stored in the working fluid, in the perfect-engine cycle is always, and whatever the fluid, the latent heat of expansion from minimum to maximum volume during the period of storage, *i. e.*, that of expansion of a gas isothermally, but under varying pressure, or that of vaporization of a liquid, also isothermally, but under constant pressure. Since the requirement of maximum efficiency is introduction of heat at a maximum and a constant temperature and its rejection at a minimum and constant temperature, it is evident that positive work only is the result of the introduction of this heat, and that it is therefore all latent heat. Similarly, the rejection of heat at the lower limit of temperature and expansion-ranges indicates negative work, and only work. In neither case does change of temperature occur and in neither case, therefore, is sensible heat transferred.

The fact that the quantity of potential energy in store in the substance as its so-called latent heat of vaporization is not in any sense a measure of the cost of power-production in the perfect-engine cycle of a stated temperature-range, whatever the working fluid, is exhibited graphically in the accompanying sketch in which *a b c d* is, it may be assumed, the cycle of Carnot, with a substance—purely hypothetical, of course—capable of accepting variable quantities of "latent" heat.

During the production of whatever vapor, the temperature and the pressure alike remain constant and, necessarily, all heat supplied the fluid must be converted into work, internal and external, and this constitutes the misnamed quantity "latent heat." Should this or another

substance receive heat in this manner to the extent indicated by $a b'$, one-half $a b$, it is evident, first, that one-half the work would be performed in the cycle, and, secondly, that just as large a quantity of the substance would be required to perform it. The amount of both heat and working fluid would thus be determined by the extent to which the substance should be capable of absorbing "latent" heat. Thus the quantity of fluid circulating per unit of time will be in the inverse proportion of its quantity of latent heat of vaporization, other things equal; while the efficiency will obviously remain unchanged and absolutely independent of the nature of the working fluid

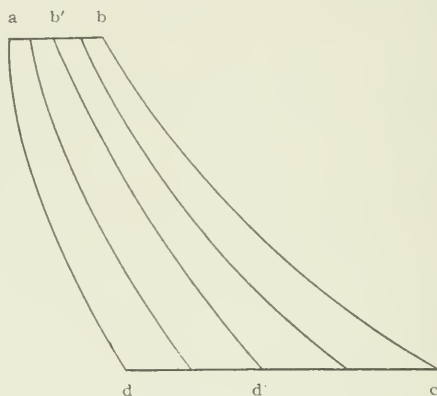


FIG. 1.—Work and latent heat.

and solely dependent upon the temperature-range of the cycle.

This is also perhaps as well shown thus: The work of the perfect-engine cycle is measured by the quantity

$$U_1 = H_1 (T_1 - T_2) / T_1.$$

Heat of vaporization, H , is supplied and it is utilized thermodynamically to the extent measured by the Carnot factor, range of temperature divided by the maximum absolute temperature. The latter is the efficiency of the cycle, the former factor the measure of the quantity of heat in action, as elsewhere stated; while the product is the measure of work performed at that efficiency per unit

weight or volume of working substance. With all fluids, the power delivered being constant as demanded by the engineer, the continued product of the latent heat, the efficiency and the number of cycles must give that measure of work.

Carnot's dictum regarding the thermodynamic identity in efficiency of all substances working in the perfect-engine cycle is plainly not applicable to comparisons of working substances where other cycles, less perfect, are adopted. Thus, a study of the form of the expression for the efficiency of the fluids worked in the Rankine or the Clausius cycle will show that the numerical value of the efficiency depends upon a function which involves both the heats of vaporization and the specific heats of the fluids. With variations of these constants, even with the same cycle, therefore, it may prove that two substances compared may give different efficiencies in a common cycle, although these differences are probably seldom important in practice. The differences which affect the extent to which initial condensation of the working fluid at the opening of the supply-valve, as, for example, between the oily and other substances, or between the steamlike and the etherlike, are probably much more important as affecting a choice of fluid; in other words, in any given cycle, with a stated temperature-range and fixed form and proportions, it is not probable that, in the ideal purely thermodynamic case, any important differences will be caused in the measure of its efficacy by change of working substance; but it is very probable that, in the real case, with its various sources of waste, thermally and dynamically, and varying relation of thermodynamic action to total energy supplied, there may be found sensible differences in the values of such substances and possibly sufficient differences in some instances to justify the selection of one in preference to others under special conditions of operation and of costs.

Hitherto, however, although the matter has been very often discussed, and both engineers and physicists have investigated the question very carefully from the point of view of theory, the ultimate deduction is still uncertain.

But it has been the common verdict of both engineers and men of science that, on the whole, steam is the most desirable single substance.

The conclusions of engineers generally, as well as of thermodynamists, have come to agree with those of Hirn, as expressed in his discussion of the heat-motors in his treatise on thermodynamics.* Hirn remarks :

“When one has clearly in mind the conditions of the problem, *i. e.*, to secure the largest practical return from the greatest temperature-range possible; and when, imbued with this principle, one glances even superficially over the tables of temperatures and tensions of various fluids, one becomes promptly convinced that the choice of the fluid to be employed, far from being a matter of indifference, is of the greatest importance. Condemned by force of circumstances to utilize but a small fraction of the available temperature of the furnace, we should at least seek to make that fraction as large as possible. Contrary to the general opinion, there are fluids which, having moderate pressures at elevated temperatures, might, if their chemical and physical properties would permit, serve our purpose. Liquids and saturated vapors having high tensions at low temperatures, such as ether, carbon-disulphide, etc., should be definitely excluded from the form of generator exposed to the direct action of the fire, and these can serve only in the utilization of low temperatures, the wastes of the thermic motors. And this is true without reference to the dangers which usually accompany the industrial employment of such substances. At 120° C. (248° F.) sulphuric ether has a tension of 10 atmospheres; a pressure accepted as the limit in the locomotive. Water only attains this tension at a temperature of 180° C. (356° F.) and we may utilize 60° greater range of temperature with the latter.

“If, after this very clear and yet superficial study, we pass to a more minute examination of the subject, we finally recognize the fact that in the choice of a liquid we are ultimately led to that which, at present at least, is found to

* “*Theorie mecanique de Chaleur*,” T. II, p. 11.

be unique. It is that which nature, fortunately, has everywhere placed at our service."

The Characteristics of the volatile as contrasted with
PRESSURES.

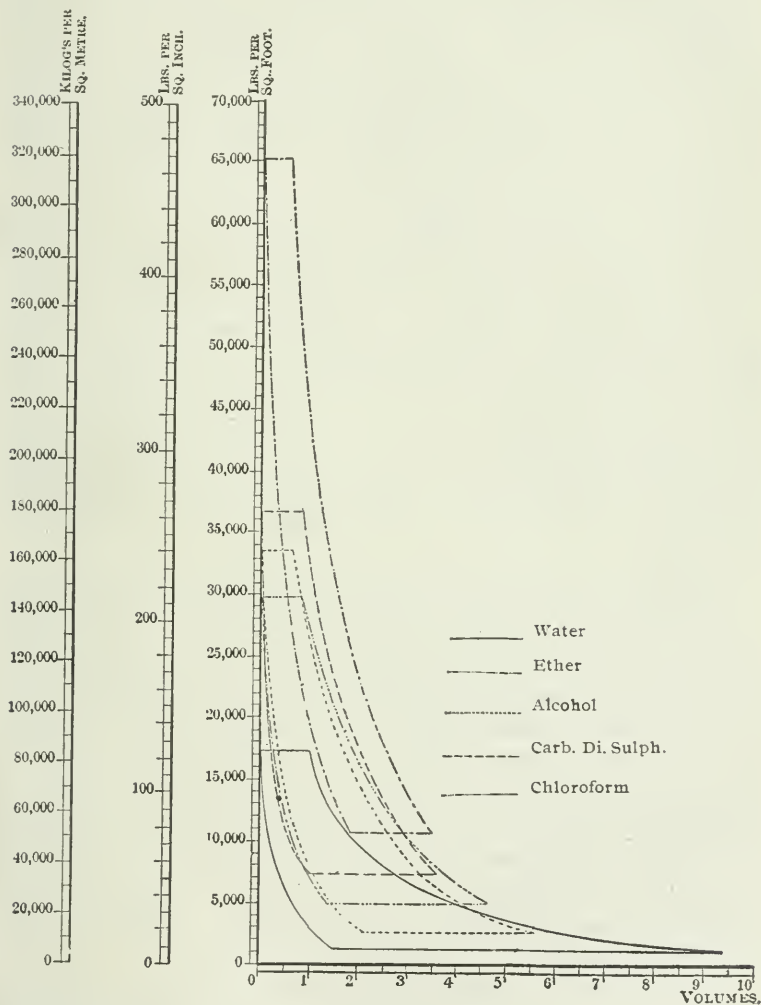


FIG. 2.—Carnot cycles. Various vapors with common temperature-range.

those of the more stable liquids and vapors are illustrated in the accompanying plate in which the Carnot cycles of water, ether, alcohol, carbon-disulphide and chloroform are

exhibited in their production within a common temperature-range.* It is here seen that the pressures usual in steam-engines and their co-ordinate pressures are assumed for steam and that the other fluids are compared with this common steam-engine cycle as a standard. The initial pressures are seen to range from 125 pounds per square inch, absolute, with the steam-engine, up to about 475 with ether; while the back-pressures similarly illustrate differences between ordinary condenser-pressure in the steam-engine and about 80 pounds above vacuum with ether, all the other substances falling in between these limits and approximating the characteristic pressures of ether or of steam as they are more or less volatile. With the same quantity of heat worked in the cycle, however, each fluid has the same area of indicator-diagram and performs the same amount of work with the same heat-supply. The difference is simply that a larger quantity of fluid must be furnished for the same work in that cycle which employs the fluid of lesser latent heat. The product of weight of fluid into latent heat must be a constant for all cycles in such case.

Were it practicable to select either of these fluids without reference to costs, dangers or inconveniences, that fluid would be adopted, in the single-fluid engine, in which the maximum available temperature-range and maximum utilizable pressure-range should most satisfactorily coincide. For the series-fluid engine, that combination would be chosen in which the primary and the secondary fluid should each best adapt itself to the limiting temperature or pressure-range of its cycle, the fluids thus placed in series then conspiring to provide that combination which should most absolutely and completely utilize the total coincident range.

Professors Wood and Jacobus have studied the physical properties of substances most practically available for substitution as the working fluids of heat-engines in competition with steam, and their results have been published in the Transactions of the Society of Mechanical Engineers.†

* *Van Nostrand's Mag.*, 1880.

† "Transactions Am. Soc. M. E.," Vol. XII, 1890.

The outcome of these determinations of important data for such substances may be seen on reference to those papers, and the tabulated results are also collated in the appendix herewith. The properties of sulphur-dioxide have especial interest at the moment. Rankine's formulas were employed in computing the latent heats of vaporization, and the numerical values closely accord with the determinations of Roche and others and with the results of experimental research, so far as they have gone.*

The determinations for ammonia have greater value than ordinarily assumed in the light of the work of the reporters upon the behavior of that fluid in heat engines. The work reported by Professor Jacobus, in the experimental determination of the latent heats of ammonia and of sulphur-dioxide, assume importance also, far above that which would have been assigned such quantities by engineers had not interest in the relative importance of other fluids than water and steam in the heat-engines been so thoroughly re-awakened by recent developments in the employment of series-fluid engines. The constants derived are tabulated in the appendix.

The most complete and instructive study of the characteristics of available working fluids for heat-engines, of which the writer has knowledge, was made at the request and under the direction of the writer, in 1884, and the outcome of the investigation, later published, attracted the attention of the profession throughout the world.†

Case I.—Comparing the various fluids studied within a common range of temperature and in the Carnot cycle, the obvious conclusion was reached that all would exhibit the same thermodynamic efficiency; but it was for the first time fully shown by the investigators, Messrs. Grant and Maury,‡ what differences exist in the cycle in positive and negative works, in pressures and volumes of unit weight of fluids. The following tables bring these differences out clearly:

* For details of methods of construction of these formulas, see "Wood's Thermodynamics."

† *Van Nostrand's Engineering Magazine*, 1884.

‡ Members A. S. M. E.

TABLE I.

Vapors.	t_1	t_2	t_3	t_4	τ_1	τ_2	τ_3	τ_4	p_1
	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Lbs. on sq. foot.
Water	342	194	193	248	803'2	655'2	754'2	709'2	17,310
Alcohol	342	194	193	248	803'2	655'2	754'2	709'2	33,712
Ether	342	194	193	248	803'2	655'2	754'2	709'2	65,328
Carbon di-sulphide. .	342	194	193	248	803'2	655'2	754'2	709'2	36,708
Chloroform	342	194	193	248	803'2	655'2	754'2	709'2	27,845

Vapors.	p_2	p_3	p_4	λ_1	λ_2	λ_3	λ_4	D_1	D_2
	Lbs. on sq. foot.	Lbs. on sq. foot.	Lbs. on sq. foot.	Thermal units.	Thermal units.	Thermal units.	Thermal units.	Lbs. per cu. foot.	Lbs. per cu. foot.
Water	1,442	8,705	4,153	869'4	975'6	908'5	940'7	'317	'029
Alcohol	3,312	17,989	9,003	286'2	370'8	311'6	336'2	1'572	'171
Ether	10,858	36,090	21,501	99'4	144	116'3	130'1	4'911	'903
Carbon di-sulphide. .	7,295	22,943	14,342	108'2	140'4	121'1	130'0	2'832	'623
Chloroform	5,189	18,433	10,936	92'6	104'6	94'0	98'8	3'611	'695

Vapors.	D_4	D_5	r_2	r_4	r_5	v_1	v_2	v_4	v_5
	Lbs. per cu. foot.	Lbs. per cu. foot.				Cu. feet.	Cu. feet.	Cu. feet.	Cu. feet.
Water	'164	'081	9'37	1'83	3'51	1	9'37	1'83	3'51
Alcohol	'866	'447	8'97	1'83	3'54	'6116	5'48	1'12	2'17
Ether	2'798	1'717	6'11	1'85	3'11	'5640	3'45	1'04	1'75
Carbon di-sulphide. .	1'827	1'180	3'56	1'47	2'18	'8980	3'56	1'32	1'95
Chloroform	2'301	1'405	5'22	1'58	2'60	'8615	4'56	1'36	2'24

Vapors.	K.	Work of Expansion.	Work of Compression.	Effective Work.	Heat used.	Efficiency.
						<i>per cent.</i>
Water	1	56,275	17,483	39,192	212,654	18'43
Alcohol	'966	67,857	28,645	39,192	212,654	18'43
Ether	'607	95,593	56,401	39,192	212,654	18'43
Carbon di-sulphide. .	'257	72,527	33,335	39,192	212,654	18'43
Chloroform	'246	71,166	31,974	39,192	212,654	18'43

The methods of treatment were those of Rankine and the physical data were derived from Regnault and Wüllner. The thermodynamic p - v diagrams are seen in the accompanying figure already referred to.

The conclusion is now perhaps evident that, while the thermodynamic efficiency is identical for all substances, as asserted by Carnot, for the ideal case and the perfect-engine cycle, it by no means follows that for less perfect cycles, or for any cycle, and with the actual engine, will the efficiencies be identical, when the influence of differences in size of engine, in pressures to be employed and limiting temperatures are studied. Final efficiency will obviously be less as the necessary volume of engine-cylinder increases.

In the above tables, the subscripts 1 and 2 indicate that the densities, D , volumes, v , etc., are measured, respectively, at the initial point of the expansion-line and its termination, at initial and final temperatures, on that line; while subscripts 4 and 5 indicate points on the compression-line employed in its location. It is seen that v_2 ranges from 3.45 to 9.37. The specific heat ranges, for the several substances, from unity with water to 0.242 with chloroform. The latent heats at the various temperatures and pressures are indicated by similar subscripts.

Case II.—A *Constant Pressure-Range* being adopted with the Rankine cycle, a similar comparison gives the following tables, where the symbols are taken as the accompanying statement.

BRITISH UNITS.

τ_1 , absolute initial temperature on the Fahr. scale.

τ_2 , absolute final temperature on same scale.

τ_4 and τ_5 , absolute temperatures of intermediate points.

t_1 , temperature on F. scale corresponding to absolute temperature τ_1 .

t_3 , temperature of condenser.

p , tension of vapor in pounds per square foot at temperature t .

λ , latent heat of evaporation in British thermal units of 1 pound of vapor at temperature t .

L, latent heat of evaporation of 1 cubic foot of vapor in foot pounds at temperature t .

v , volume corresponding to ratio of expansion r .

w , work (in foot pounds) done per cubic foot of vapor at temperature t_1 .

H, total heat (in foot pounds) used per cubic foot of vapor at temperature t .

F, pounds used per horse-power per hour.

M, relative size of cylinder to produce the same power.

TABLE II.

Vapors.	τ_1	τ_2	τ_3	τ_5	t_1	t_3	D_1	D_3	D_5
Water	803	655	754	709	342	104	'317	'164	'081
Alcohol	752	617	673	637	291	104	'834	241	'119
Ether	691	537	673	637	230	104	1'400	1'132	'712
Bi-sulph. of carb. . .	727	556	673	637	266	104	1'399	'780	'487
Chloroform	747	581	673	637	256	104	2'171	'893	'531

Vapors.	p_1	p_2	p_3	p_4	p_5	λ_1	λ_3	λ_5	K
Water	17,310	1,442	153	8,703	4,512	869'4	908'5	940'7	1
Alcohol	17,310	1,442	373	4,730	2,264	313'2	358'2	383'4	'871
Ether	17,310	1,442	2,526	13,796	8,420	135'0	139'7	148'0	'569
Bi-sulph. of carb. . .	17,310	1,442	1,721	9,261	5,663	126'0	137'0	143'5	'249
Chloroform	17,310	1,442	1,020	6,763	3,911	94'7	102'6	106'4	'242

Vapors.	L_1	L_2	τ_2	τ_4	τ_5	W	H	E	M	F
								<i>p. c.</i>		
Water	212,654	21,976	9'37	1'83	3'57	54,829	272,528	20'12	1	11'44
Alcohol	201,861	23,606	9'92	3'97	8'12	54,196	300,088	18'06	1'071	30'48
Ether	146,030	16,863	12'06	1'25	2'05	31,058	324,206	13'85	2'275	89'24
Bi-sulph. of carb. . .	136,219	16,038	9'00	1'87	3'06	35,545	179,973	19'75	1'480	78'15
Chloroform	158,851	17,771	10'29	2'68	4'66	47,609	232,685	20'46	1'264	90'30

The very great differences between limits and ranges of temperature and pressure, in the comparison of water and the volatile fluids, is here well brought out by observing the

data given in the two cases. The important fact that the practical limits of temperature and of pressure in heat-engines employing these various fluids as working substances are necessarily widely separated in each fluid, and are in no case coincident, is also evident; while the possibility of securing a higher net efficiency from a system in which the one fluid is used in supplement of another in such manner as to more nearly bring the upper limit of manageable temperature to coincide with the limit of allowable pressure and the lower limit similarly depressed to a point at which the pressure and the temperature range have coincident practical boundaries, becomes no less obvious.

In this case, we find sensible differences in efficiency, naturally, and, in the case of water and ether, a wide difference, in the relation of 20 per cent. to 14. The relative sizes of engine to produce equal power, M , varies between the standard, unity, for water and steam, to 2.27 for ether and 1.48 for carbon-disulphide. This means that, at low pressures certainly, the larger engine required may place the more volatile substance at a real disadvantage beside steam. The values of F , the weights of the fluid demanded in the unit of time for the unit of power, vary more strikingly than any other figures given, ranging from 11.44 pounds per horse-power hour for steam to about 90 pounds for ether and chloroform. This is not, however, as important a matter as it might seem at first; since it only means that a larger quantity of fluid is required to convey a given amount of heat where the "latent heat" is a small, than where, as with water, it is a large quantity. The figures, however, bring out very strikingly the fact that, in such comparisons, it is only the measures of efficiency and of thermal units per unit of power and of time that give the measures of the cost of power. The phrase, "pounds of steam per horse-power hour," has here no significance.

Another interesting point appears in this comparison: that the common pressure-range adopted, as fixed by customary working of the steam-engine, is not suitable for all fluids. With both ether and carbon-disulphide, the terminal pressure falls below the back-pressure line, and their work-

ing range, for best effect, should be lifted to a higher point on the scale.

Case III, resembling *Case II*, except that the terminal pressure is elevated sufficiently to evade the objection just mentioned, the following results are obtained:

TABLE III.

Vapors.	τ_1	τ_2	τ_3	τ_4	τ_5	t_1	t_3	D_1	D_2	D_4	D_5
Water	803	655	754	709	342	104	104	'317	'029	'164	'081
Alcohol	752	619	673	637	291	104	104	'834	'080	'241	'119
Ether	691	583	673	637	230	104	104	1'400	'310	1'132	712
Carbon di-sulphide	727	601	673	637	265	104	104	1'399	'289	'780	'487
Chloroform	747	601	673	637	286	104	104	2 171	'293	'893	'531

Vapors.	p_1	p_2	p_3	p_4	p_5	λ_1	λ_4	λ_5	K	L_1	L_2
Water	17,310	1,442	153	8,703	4,512	869'4	908'5	940'7	1	212,650	21,950
Alcohol	17,310	1,507	373	4,730	2,264	313'2	358'2	383'4	'871	201,861	24,565
Ether	17,310	3,524	2,526	13,796	8,420	135'0	139'7	148'0	'569	146,030	47,936
Carbon di sulphide	17,310	3,245	1,721	9,261	5,663	126'0	137'0	143'5	'249	136,219	33,331
Chloroform	17,310	2,092	1,020	6,763	3,911	94'7	102'6	106'4	'242	158,851	24,885

Vapors.	v_2	v_4	v_5	W	H	E	M
						<i>per cent.</i>	
Water	9'37	1'83	3'51	54,829	1,330,639	20'12	1
Alcohol	9'51	3'97	8'12	53,786	1,465,207	17'92	1'035
Ether	4'85	1'25	2'05	33,357	1,094,722	14'83	'345
Carbon di oxide	4'31	1'87	3'06	33,358	878,729	18'53	7'26
Chloroform	7'24	2'68	4'66	44,894	1,136,084	19'29	'944

These figures show an evident improvement in the working conditions affecting the more volatile fluids, and in this case steam has highest efficiency and carbon-disulphide requires the smallest engine for the same work.

[To be continued.]

Book Notices.

The Chemistry of the Terpenes. By F. Heusler, Ph.D. Authorized translation by Francis J. Pond, M.A., Ph.D. 8vo, 435 pages and index. Philadelphia: P. Blakiston's Son & Co. Cloth. \$4 net.

This excellent volume is an acceptable contribution to chemical literature. Great progress has been made in late years in the study of the terpenes, the principal ingredients of the essential or volatile oils. Much of the original literature is in other languages than English; moreover, owing to the rather restricted applications of the researches, the ordinary text books have given but brief summaries. A generation ago, indeed, all that was known about the essential oils might have been expressed in a very few pages. The textbooks of that day usually gave a brief account of some of the more important oils, stating the striking isomerism observed with regard to the hydrocarbons present. The investigations of O. Wallach have been the principal "road-breaking" element in the modern progress. He succeeded in solving the general chemistry of the essential oils so that the examination of them can be systematized and the different proximate constituents identified with comparative ease. It is now known, that while the natural volatile oils consist largely of hydrocarbons, yet these are usually accompanied by oxidized bodies, analogous to the camphors. The group of camphors has, therefore, been brought into close structural relations to the terpenes and is considered in this book. Any one who has given even superficial attention to the trade literature in this field is aware of the great progress that has been made in the production of synthetics. Not only have many of the natural products been accurately imitated, but derivatives and isomers have been obtained in great number.

The translation of Heusler's book will afford an opportunity to English-speaking students to get a synopsis of the present state of the subject. The translation is very well done. We commend the care taken to avoid mere literal rendering of German idioms and German nomenclature. The mechanical execution of the book is also good and, altogether, it reflects credit on author, translator, printer and publisher. It relates principally to the pure chemistry of the topic; the analytic and industrial features are not within its scope.

H. L.

Histoire des Mathématiques dans l'Antiquité et au Moyen Age. Par H. G. Zeuthen, Professeur à l'Université de Copenhague. Edition Française, Revue et Corrigée par l'Auteur. Traduite par Jean Mascart. Un volume in-8 de xv-296 pages, avec 31 figures. Paris: Gauthier-Villars, 1902. (Price, 9 fr.)

The introduction of this work treats of prehistoric mathematics, and of the state of the science among the Egyptians and Babylonians. Following are chapters on mathematics as developed by the Greeks, and in India. The work concludes with an historical sketch of the sciences during the Middle Ages, especially dealing with the contributions of the Arabian mathematicians and the development of the sciences in Europe.

W.

Die Eis- und Kälteerzeugungs-Maschinen; ihr Bau und ihre Verwendung in der Praxis. Ein Compendium der gesamten Kälte-Industrie. Von Richard Stetefeld, diplomierter Ingenieur zu Pankow, Berlin. Stuttgart: Verlag von Max Waag, 1901.

This treatise makes a large octavo volume of nearly 500 pages, with thirteen plates and 340 illustrations in the text.

The subject is divided into, (1) an historical and descriptive portion, in which is given a review of the development of the art of refrigeration, and a series of chapters giving detailed descriptions of the various types of refrigerating machines, cold-air machines, absorption machines, vacuum machines; (2) a theoretical part, in which is presented the fundamental physical principles and the mechanical theory of heat; (3) a constructive part, treating in detail of the several mechanical elements—compressors, condensers, etc.—entering into the construction of refrigerating machines; (4) erection and operation; (5) installation, treating of the special location of machines for different kinds of service—in breweries, abattoirs, cold-storage houses and special forms of service; (6) duty-tests of refrigerating machines in practice, in which are treated instruments and methods, with examples. A series of tables useful for reference is appended.

The treatise is the work of an engineer who had an extensive practical experience, and should prove a useful addition to the literature of the subject.

W.

Armature Windings of Direct-Current Dynamos: Extension and application of a general winding rule. By E. Arnold, Engineer and Assistant Professor in Electrotechnics and Machine Design at the Riga Polytechnic School. Translated from the original German by Francis B. De Gress, M.E., Chief of Testing Department, Crocker-Wheeler Company. With 146 illustrations. 8vo., pp. vi + 124. New York: D. Van Nostrand Company. 1902. (Price, \$2.)

In this work Professor Arnold has formulated a rule for the solution of the problems in winding armatures for direct-current machines, which not only embraces all known windings—ring, drum and disk types—but also affords a general solution of the winding problem.

The designs and illustrations treated include all of the well-known forms and a number of new designs. The work will doubtless be very useful to electrical engineers.

W.

Electric Power Transmission: A practical treatise for practical men. By Louis Bell, Ph.D. Third edition, revised and enlarged; pp. 952. New York: *Electrical World and Engineer*, N.D.

The author has thoroughly revised the present edition of this well-known treatise, bringing it in touch with the present, and with the result of considerably enlarging it by the addition of new matter and numerous illustrations of recent plants and apparatus. A chapter on Commercial Electrical Measurements has been added; and in the final chapter on High Voltage Transmission, the author has sought to incorporate the latest developments of the art.

The present edition is illustrated with 21 full-page plates and 285 cuts in the text.

W.

Tir des Fusils de Chasse. Par Journée, Lieut-Colonel du 69e Régiment d'Infanterie. 2e édition, entièrement refondue. Paris: Gauthier-Villars, 1902.

The work is a complete treatise on sporting-arms and ammunition.

The first edition of this work, issued about twelve years ago, contained the results of a considerable number of experiments made with the old type of sporting gunpowders then in use.

In the present edition the author has supplemented these results by a series of similar experiments made with the modern pyroxyline powders which have come largely into use for sporting-arms. W.

Text-Book of Qualitative Chemistry for studies of water solution and mass-action. By Albert B. Prescott, Ph.D. and Eugene C. Sullivan, Ph.D. Eleventh edition, entirely rewritten. New York: D. Van Nostrand Company, 1902. (Price, \$1.50.)

The eleventh edition of this work has been thoroughly modernized, and it can be commended to teachers and students of the science. W.

A Philosophical Essay on Probabilities. By Pierre Simon, Marquis de Laplace. Translated from the sixth French edition by Fred Wilson Truscott, Ph.D., Havre, and Fred'k Lincoln Emory, M.E., Nor. Poly. Inst. First edition. First thousand. New York: John Wiley & Sons. London: Chapman & Hall, Limited, 1902. (Price, \$2.)

The translators appear to have made an elegant and admirable English version of the classic work of Laplace. W.

Franklin Institute.

[*Proceedings of the Stated Meeting held Wednesday, September 17, 1902.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 17, 1902.

President JOHN BIRKINBINE in the chair.

Additions to membership since last report, 17.

The Secretary reported the resignations of Prof. Arthur Beardsley and Henry C. Brolasky from the Board of Managers.

An election resulted in the choice of Mr. Henry T. Townsend in place of Professor Beardsley, and of Mr. Jawood Lukens in place of Mr. Brolasky.

Under suspension of the rules, amendments to the By-Laws, offered respectively by Profs. F. L. Garrison and L. F. Rondinella, were adopted, severally and collectively, as follows :

ARTICLE III.—*Members.*

SEC. 7. Any member whose dues are more than three months in arrears shall be notified by the Actuary. Should such dues not be paid when they

become six months in arrears, the privileges of membership shall be suspended. When nine months in arrears such member shall be again notified, in form to be prescribed by the Board of Managers, and if such dues become one year in arrears, the said member shall forfeit all connection with the Institute. The Board of Managers may, however, for cause by it deemed sufficient, extend the time for payment and for the application of these penalties.

The Board of Managers may, for sufficient cause, temporarily excuse from payment of annual dues any member who, from ill-health, advanced age, or other good reason assigned, is unable to pay such dues; and the Board may remit the whole or part of dues in arrears, or accept in lieu thereof desirable additions to the library or collections.

Every person admitted to membership in the Institute shall be considered as liable for the payment of dues until he shall have resigned, been dropped or have been relieved therefrom by the Board of Managers.

ARTICLE VI.—*Election of Officers, Etc.*

SECTION 1. An election for officers and for members of the Committee on Science and the Arts shall be held on the date of each Annual Meeting. At this election the President, the Secretary and the Treasurer shall be elected to serve one year, and one Vice-President, eight Managers, one Auditor, and twenty (20) members of the Committee on Science and the Arts to serve for three years, or until their successors are elected.

SEC. 2. Voting at annual elections shall be by letter ballot, and no vote shall be cast by proxy, nor received from a member in arrears.

SEC. 3. Nominations for the annual election for officers and for members of the Committee on Science and the Arts shall be presented in writing at the stated meeting in the month of December. Each nomination paper must be signed by at least two members in good standing who shall certify that the candidate will serve if elected. After the nominations are closed, the President shall appoint seven members, who are neither officers nor nominees, to act as tellers of the election. The list of nominees shall promptly be posted at the Institute and incorporated (with directions for voting) in a ballot to be sent to each member by the Secretary at least one week before the date of the election. Each ballot shall be accompanied by a return envelope addressed "To the Tellers of Election" and provided with a space for the signature of the member voting.

SEC. 4. On the date of the annual election, and at an hour previously designated by their chairman, the tellers shall meet at the Institute and count all legal votes that have been received by mail or placed in the ballot box before 8 o'clock P.M.; and when the count is completed they shall report to the annual meeting of the Institute the total number of ballots cast, together with the number of votes received by each candidate. Thereupon, the presiding officer shall announce the names of the candidates who received the plurality of votes for each office, and shall declare them elected officers of the Institute for the ensuing terms.

ARTICLE XII.—*Of Committees.**(Committee on Science and the Arts.)*

SEC. 2 (paragraph 7). The committee shall report all vacancies occurring in their body, whether by neglect of duty or otherwise, to the stated meeting of the Institute next ensuing, at which such vacancies shall be filled by election.

ARTICLE XIV.—*Order of Business.*

SEC. 3 At the Annual Meeting, the tellers' report may be received and read by the Secretary immediately after the conclusion of any number of the order of business.

ARTICLE XV.—*Rules.*

Omit Rule Seven.

Rule Eight becomes Rule Seven.

ARTICLE XVI —*Board of Managers.*

SEC. 5. All vacancies in the Board of Managers shall be filled by an election at the next stated meeting of the Institute.

ARTICLE XVII.—*Amendments.*

Proposals for amendments to these by-laws shall be posted at the Institute at least ten (10) days before a stated meeting, and may then be presented in writing signed by at least two members in good standing. By a majority vote of the members present at this meeting they may be considered, amended, referred, postponed, rejected, or ordered to be voted upon at the date of the next stated meeting. In the latter event, the President shall appoint tellers, and the vote shall be taken by letter ballot and reported at the next stated meeting in the manner provided in Article VI for the election of officers. If two-thirds of the votes cast are in favor of the proposed amendment, it shall be declared adopted; except that amendments to Article II, relating to Capital Stock, must be ratified by a majority of the stock represented at a subsequent meeting specially called for this purpose.

Mr. S. L. Sinclair, representing the D'Olier Engineering Company, of Philadelphia, read a paper on the De Laval Steam Turbine, which was illustrated by an exhibition of parts of the apparatus and numerous lantern slides.

After some discussion, the subject was referred to the Committee on Science and the Arts.

Mr. F. E. Ives exhibited and described an improved apparatus for making stereoscopic photomicrographs. The subject was illustrated by an exhibition of the apparatus and of a number of stereoscopic views made with the apparatus. The invention was referred to the Committee on Science and the Arts.

The President announced that the question of the "Mitigation of the Prevailing Smoke Nuisance within the City Limits" had been reserved for discussion, and, at the request of the presiding officer, the Secretary read a brief abstract of the action taken by the Institute on this subject in the year 1897, at the request of the local Bureau of Health. The sentiments of the Institute were finally expressed in the following preamble and resolutions, which were

formally transmitted to the Bureau of Health and to the Presidents of Councils, viz :

WHEREAS, The Bureau of Health of the city of Philadelphia has requested the Franklin Institute to discuss the question of Smoke Prevention, and to offer practical suggestions relative thereto; and,

WHEREAS, The use of bituminous coal for fuel is increasing in this city and is likely so to continue in the future; and,

WHEREAS, It appears, from the testimony presented to the Institute, that it is practicable to burn bituminous coal in suitably constructed furnaces without creating a smoke nuisance;

Therefore, Be it resolved, that it is the opinion of the Institute that the continuous or frequent discharge of dense black smoke from furnaces of stationary boilers is avoidable, and should not be permitted within the city limits.

Resolved, That the emission of smoke from locomotives and furnaces, other than those of stationary boilers, might be greatly reduced if the co-operation of firemen and employers were enlisted with an earnest intention to abate the nuisance; and more especially, could the railway companies be induced to use anthracite coal or coke in the furnaces of the locomotives used for local service in the train-yards within the city limits.

Resolved, That a copy of these resolutions be sent to the Mayor, to the President of the Bureau of Health and to the Presidents of City Councils.

Mr. John M. Hartman, member of the Institute and of City Councils, was thereupon invited to open the discussion. The subject was discussed by Messrs. Hartman, Wm. E. Lockwood, Wm. B. LeVan, Spencer Fullerton, Wm. Trautwine, the Chairman and others.

Adjourned.

WM. H. WAHL,
Secretary.

Committee on Science and the Arts.

(*Abstract of proceedings of the stated meeting held Wednesday, Sept. 3, 1902.*)

MR. THOMAS P. CONARD in the chair.

The following subjects passed first reading :

(No. 2227.) *Electromagnetic Geological Balance*.—F. J. Estrada, Mexico.

(No. 2231.) *Screw-Cutting Lathe*.—Otto E. Evans, York, Neb

(No. 2232.) *Improvements on the Manufacture of Open-Hearth Steel*. — Benjamin Talbot, Philadelphia.

(No. 2236.) *Crushing and Grinding Rolls*.—Gerdt A. Gerdtzen, Winona, Minn.

(No. 2241.) *Compartment-Drawer Bottom* —John Gowdy, Philadelphia.

(No. 2244.) *Blount Door-Check*.—The Yale & Towne Manufacturing Company, Stamford, Conn.

(No. 2245.) *System of Motor Control*.—H. Ward Leonard, Bronxville, N. Y.

In the absence of a quorum, final action on a number of reports was postponed. Adjourned.

W

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

CHEMICAL SECTION.*

The Conversion of Amorphous Carbon to Graphite.

BY FRANCIS J. FITZGERALD.

Chemist to the International Acheson Graphite Company.

Member of the Institute.

The commercial production of graphite from amorphous carbon having been brought to a successful issue by the Acheson process, the object of the following article is to set forth certain results which have been obtained by various experimenters and have a bearing on the subject. No attempt will be made to review all the work that has been done, but rather to collect in one place some of the more important experiments and speculations which are connected with the relations of amorphous and graphitic carbon.

The earliest systematic experiments on the effect of the high temperature obtainable by electrical means on carbon were those of M. Despretz.† In his experiments, Despretz

* Read by title.

† *Comptes Rendus*, T. XXIX, No. 25, pp. 709-724.

used a battery of 600 Bunsen cells which could be connected up in various ways, according to the nature of the work required, and with these he tried the effect of high temperatures on different varieties of carbon: Retort carbon, anthracite coal, graphite, sugar carbon, carbon obtained by decomposing turpentine in a strongly heated porcelain tube, and finally on diamond. He states, that so far as he could discover, all previous experimenters had come to the conclusion that "carbon is fixed and infusible." Referring to an earlier communication (July 9, 1894) he says: I proved (there) that carbon is volatile like all the bodies called refractory. * * * This volatilization appears in the form of a black cloud which arises from the whole surface of the carbon and deposits, in great part, on the walls of the vessel in which the carbon connecting the two poles of the battery is placed. * * * As I found that carbon dissipated rapidly, both by volatilization and combustion, I tried to diminish the volatilization and eliminate the effect of combustion by working in nitrogen or in a gas that would not support combustion, at a pressure greater than that of the atmosphere."*

The apparatus used by Despretz for these experiments consisted of a cast-iron box, having a capacity of about 10 liters, and provided with a movable cover so that capsules could be placed above and below the material treated with the current or the arc. A vertical rod passed through a leather stuffing box in the cover, and a similar rod passed horizontally through one of the walls of the box. A holder of carbon was attached to each rod. The interior of the apparatus could be observed during the operation through two holes closed with thick glass. Two tubes were also provided, one of which was connected to a manometer, while the other made communication either with an exhaust or compression pump. By means of this apparatus, a current could be passed through a piece of carbon, connecting the carbon holders attached to the vertical and horizontal rods, while in a vacuum or in a gas. In order to experiment with an arc, Despretz had another cover pro-

* *Ibid.*, p. 710.

vided with two rods, at the end of which were attached the carbon holders and between which an arc could be drawn, while with the third rod a piece of carbon could be introduced into the arc. Despretz describes various experiments in which he placed carbon rods between the two electrodes and causing a current to pass through them bent the rods, and makes his first mention of graphite in the following experiment. The carbon rod, 2 centimeters long and 2 millimeters in diameter, was placed between the electrodes, and the current from the 600 cells, arranged in twelve series of fifty elements, was passed through it with the result that the rod bent and broke, the upper part showing an enlargement at the fracture. This enlarged portion resembled "slag" and the ends of the carbon were graphite. In a note on this point Despretz says:

"These experiments are always complex. I describe experiments in which the carbon is bent; but as this result can only be obtained at the highest temperatures, it happens at the same time that in nearly every case a part of the carbon fused and changed into graphite."*

Several other experiments are described in which carbon rods are heated in a similar manner and afterwards found to be graphite. In one of them an electrode, formed of carbon, had "swelled up and was converted into graphite." In some other experiments in which sugar-carbon powder was used for making a close contact with the holders, "certain globules in the powder had been formed by the heat; and in some cases the transformation of the powder into graphite was complete." These phenomena are taken as evidence of fusion.

Despretz next describes how a carbon filament is introduced into the arc, and in one of these experiments with a kind of carbon not indicated the end of the rod swelled up and was converted into graphite. In another experiment a piece of carbon made from turpentine was introduced into the arc with the result that it "shows some points on the heated end which appear to be fused. This end has acquired the properties of graphite, making marks like that sub-

* *Ibid.*, p. 714.

stance, but it does not at once become so brilliant on rubbing, nor is it as soft to the touch."

Experiments are next described in which an arc is made to play on pieces of carbon placed in a sugar-carbon crucible which forms the positive electrode. The most interesting of these experiments, in view of the modern manufacture of graphite, are described as follows:

"Some nearly pure anthracite, treated in the same way, spread out on a crucible like a black glass. . . . A much larger piece of this substance (anthracite) treated in the same manner by the battery, which had been weakened by numerous experiments, exfoliated. The part which received the direct action of the heat became bluish gray in color and was clearly graphite. The part on the edges of the crucible became less hard but was not yet graphite."*

The last experiments we shall notice are described as follows:

"I covered and impregnated some acicular rods of carbon with more fusible materials: silica, alumina and magnesia, in order to see if the presence of more fusible substances made the fusion of the carbon easier in the heat from the battery. The silica, alumina and magnesia were dissipated in the form of vapors and the carbon remained behind retaining its (original) properties.

"I placed an acicular rod of carbon in a clay crucible, filled the latter with well-dried sand, and then passed a current through the carbon which fused and volatilized. I found a sort of very hard fulmineous tube, of which the inside was lined with smoked quartz. The inside diameter was at least ten times that of the carbon."†

As the result of his experiments Despretz concludes that:

"In a vacuum, carbon manifestly vaporizes at the temperature to which it is raised by a battery of 500 to 600 Bunsen cells connected in five or six series. In a gas the vaporization is more gradual but likewise occurs.

"Carbon brought to the temperature which we obtained in our experiments may be bent, welded and fused.

* *Ibid.*, p. 719.

† *Ibid.*, p. 720.

"Any carbon which is submitted for a long time to a high temperature becomes proportionately softer. Finally it is transformed into graphite."*

In 1870, M. Berthelot published a very interesting article on the allotropic forms of carbon. He refers to the loose way in which the term graphite is employed, as follows:

"Many varieties of amorphous carbon, such as natural plumbago and various artificial carbons, have been associated with graphite. Thus, Berzelius identifies with metallic carbons, coke obtained from the calcination of oil, also charcoal and lampblack after they have been exposed for some time to an intense red heat. In the same way Despretz applies the name graphite to retort and sugar-carbons after they have been heated some time either by the enameling lamp or the electric arc. M. Regnault and M. Caron have designated certain gas-retort carbons with the same name and otherwise conform to Berzelius' opinion.

"If I cite these authorities to specify the sense which has been attached in general, up to the present, to the word graphite, it is because the definition of this substance, whenever it is not crystalline, lacks strictness and gives rise to many ambiguities. For example, the property of marking paper which has often been cited as characteristic of graphite does not belong either to metallic carbons or to certain carbons which I shall class with true graphites; while it is present in lampblack and some other amorphous carbons."†

M. Berthelot then goes on to describe Brodie's discovery of the production of graphitic oxide by the oxidation of graphite with nitric acid and potassium chlorate. As a result of his study of Brodie's process, Berthelot describes a method of distinguishing the various forms of carbon:

"This method consists in oxidizing the carbon at a low temperature and examining the products formed, under these conditions:

* *Ibid.*, p. 724.

† *Annales de Chimie et de Physique*, p. 392, 3 Serie, Tome xix.

"(1) Diamond is not appreciably oxidized, even by long and repeated treatments, and this is the case whether ordinary or black diamonds are concerned.

"(2) The different varieties of amorphous carbon are completely changed into humic-like acids, yellowish brown in color and soluble in water; the properties of these acids vary, following the carbons which yield them.

"(3) The different varieties of true graphite are changed into corresponding graphitic oxides; the properties of these oxides vary notably with the nature of the graphite from which they are produced; but all are characterized in one way by their insolubility, and above all by their property of decomposing rapidly and with deflagration when heated."*

Berthelot then describes the method he employs for treating the carbon under examination with the oxidizing mixture; calls attention to the fact that the various products of oxidation would lead to a separation of the graphite and amorphous carbon classes into numerous distinct groups, and goes on to say:

"Whatever these more subtle distinctions which require further research may be, the method of analysis which I propose permits a very clear recognition of the three principal groups which comprise the varieties of carbon, viz.: diamond, amorphous carbons and graphites. I propose hereafter to reserve the name graphite exclusively for those carbons which yield a graphitic oxide; this definition will be found to be sufficiently precise and will not give rise to the old ambiguities."†

After describing the method of applying his tests, Berthelot takes up its application to graphites:

"There exist many distinct varieties of graphites; I shall notice especially three, which I have successfully distinguished:

- (1) The graphite of natural plumbago.
- (2) The graphite of cast-iron.
- (3) Electrical graphite, obtained by the transformation

* *Ibid.*

† *Ibid.*

of different varieties of carbon under the action of the electric arc.

* * * * *

"A. PLUMBAGO.

(The variety observed by Mr. Brodie).

"The graphitic oxide formed occurs, in the moist state, as micaceous plates of a pale yellow color, insoluble in all solvents (neutral, alkaline or acid) and unaltered by repeated oxidizing reactions. It contains neither chlorine nor nitrogen.

"When it is dried, even at the ordinary temperature, it agglomerates in brown, amorphous, tenaceous plates in which the original structure disappears.

* * * * *

"B. GRAPHITE FROM CAST-IRON.

"The graphitic oxide from cast-iron occurs in greenish yellow scales, better developed than those of plumbago, and which do not agglomerate in any way during desiccation, but still retain a very characteristic yellow or greenish yellow tint. This characteristic distinguishes them clearly from the oxide of plumbago.

* * * * *

"C. ELECTRIC GRAPHITE.

"The graphitic oxide of electric graphite has the appearance of a maroon-colored powder, and does not agglomerate sensibly. * * *"

Next follows an interesting study of the relations between graphitic compounds and organic compounds properly so called, after which there is a discussion of "the actual states of carbon," where the oxidizing action is applied to the usual varieties of carbon, to carbon that has been treated in various ways, and, finally, to carbon prepared by the decomposition of its compounds with numerous other bodies, such as hydrogen, oxygen, metals, etc. Passing over the experiments on the "usual varieties," we come to the consideration of the effects of heat:

* *Ibid.*

"By the action of heat alone, that is to say, by calcining graphites and various amorphous carbons at a white heat in an atmosphere of hydrogen, I never was successful in passing from one group to another; only amorphous carbons appeared to show some increase in cohesion. * * *

"Chlorine, at a white heat, does not change charcoal into graphite nor graphite into amorphous carbon; it is known, besides, that chlorine does not attack free carbon. Iodine at a red heat does not change coke into graphite; on the other hand, iodine brings about this transformation by acting on nascent carbon, as will be shown later.

"The action of oxygen is more complicated. It, in fact, gives rise simultaneously to an extreme elevation of temperature and to a formation of dioxide and monoxide of carbon. Carbon submitted to this double action may be studied by burning a retort-carbon rod, previously heated to redness, in a stream of oxygen. When the end of the rod is fully incandescent it is rapidly extinguished by plunging it in cold water. Then the extreme point of the pencil is removed, care being taken to confine oneself as far as possible to that portion which has been most strongly heated. The carbon thus treated is no longer composed exclusively of amorphous carbon, but contains a small quantity of graphite formed by the double action of heat and oxidation.

* * * * *

"No action is more worthy of interest than that of electricity. I have examined, by the new method of analysis, the carbon poles used in the electric light. It is known that under this action the carbon is vaporized and passes from the positive pole, which becomes continually smaller, to the negative pole, which becomes covered with a spongy mass. I oxidized the carbon powder collected from a large number of carbons that had been used in producing electric light and obtained great quantities of graphitic oxide. This graphitic oxide, and, consequently, electric graphite, are not identical with those of cast-iron or those of plumbago.

* * * * *

"The formation of electric graphite does not occur indifferently at the two poles. The negative poles, thickened by

the transport of the carbon, alone yielded a large quantity of graphitic oxide; while the corresponding positive poles, attenuated by the action, only contained traces; moreover, these were probably due to the necessarily imperfect separation of the carbon which deposited on the poles during the action of the electric light.

"Nevertheless, the transformation into graphite does not necessitate the preliminary volatilization of the carbon. In fact, the capsules of sugar carbon, softened by the arc from a battery of 600 elements, were found to be, in great part, changed into graphite at the negative pole."*

The capsules referred to were those used by Despretz in his experiments.

Omitting details, the results of the next experiments are as follows:

Decomposition of hydrocarbons by heat alone yields amorphous carbon.

Decomposition of methane by the electric spark yields amorphous carbon with a trace of graphite.

Decomposition of methane by chlorine yields amorphous carbon.

Decomposition of benzene, naphthalene and other hydrocarbons at 280° , as iodine and hydrochloric acid, yields amorphous carbon; but at higher temperatures decompositions with these reagents can be effected with the production of considerable quantities of graphite which appear to be analogous to the electric variety.

Lampblack, produced by the combined action of heat and oxidation, yields traces of graphite.

Decomposition by heat of chloride of carbon yields graphite in considerable quantities, and the same results are obtained by the decomposition of carbon bisulphide, though the graphite obtained from the latter will not mark paper.

Cyanogen, decomposed by the electric spark, yields amorphous carbon with traces of graphite.

Sodium carbonate, decomposed by heating with phosphorus, yields amorphous carbon and a little graphite.

* *Ibid.*

Red-hot sodium reacting with sodium carbonate yields a small quantity of carbon composed, in great part, of graphite. The experiments with carbide of boron and certain metallic carbides are of such interest, in view of later work, that they will be quoted in full.

"Carbide of Boron.—It is known that M. H. Saint-Claire Deville has designated by the name of adamantine boron a variety of crystalline boron, which is hard and brilliant and contains a certain percentage of carbon. It is easy to separate the carbon by treating the boron with a current of dry chlorine at a red heat. I have effected this separation at two very different temperatures, namely: at a temperature lower than that of the softening of glass, and at a temperature near that of the fusion of porcelain. In both cases the carbon was composed of graphite, transformable into graphitic oxide and not containing the faintest trace of diamond. The only difference between the two experiments was, that the graphite prepared at a dull red heat was amorphous, while the graphite prepared at a white heat was crystallized in the hexagonal form well known to mineralogists.

"The latter carbon was deposited, in part, at some distance from the place where the boron had been originally placed—a phenomenon of transport which is probably due to the formation of a double chloride of carbon and boron. Some of the crystals, on account of an unequal development of their angles, showed in a striking manner under the microscope the appearance of truncated octahedra, calculated to lead a prejudiced mind into error. Observed in place, that is to say, on the surfaces where they were deposited, these crystals presented a singular luster and brightness which is never looked for in a substance like graphite. Nevertheless, the form of these crystals, when examined, as well as their transformation into graphitic oxide, leaves no room for any doubt.

"Carbide of Iron.—It is known that graphite separates from cast-iron in crystalline plates. I examined likewise the combined carbon in iron. It was separated from white cast-iron by two distinct processes, namely: by the action

of chlorine at a dull red heat and by the action of mercuric chloride (Boussingault's process).

"The carbon obtained in this way is, in both cases, composed of a mixture of amorphous carbon (predominant) with a little graphite. It would be interesting to know if there exists some relation between the various properties of cast-irons and steels and the amorphous or graphitic nature of the carbon which is found there in the combined state.

"*Carbon from Manganese.*—M. Caron was kind enough to give me a specimen of carbon which he had separated from some metallic manganese prepared by him. This specimen was composed entirely of amorphous carbon.

"Recapitulating, the carbon separated from the carbides of hydrogen by the action of heat does not contain a trace of graphite; while the carbon separated from sulphide and chloride of carbon by the action of heat or from boron by the action of chlorine contains a considerable quantity of graphite. The carbon separated from carbon dioxide (combined with soda) cannot be obtained under conditions as simple or as free from secondary complications; with this reservation, we have seen that the carbon separated either by means of phosphorous or sodium contains a certain proportion of graphite. It is the same with the carbon separated from organic compounds by incomplete combustion, that is to say, under the combined action of heat and oxygen.

"I believe it results from these observations that carbon, in separating from hydrogenous compounds, assumes by preference the state of amorphous carbon; while carbon separating from its combinations with chlorine, sulphur, boron and perhaps oxygen under the action of heat, shows a certain tendency to assume the state of graphitic carbon. I have already pointed out an analogous contrast between the several states of sulphur separated from its combinations. Finally let us add, that graphitic carbons and amorphous carbons seem to represent, not the several states of carbon itself, such as would exist in its compounds, but certain corresponding polymeric states of that element.

"All these comparisons, I repeat, are of the same order

as those which result from the study of the manifold states of sulphur and phosphorus in their combinations. But there exist here certain analogies and certain dissimilarities on which it is important to insist.

"In fact, sulphur in its various states has the same specific heat, and this is also the case with ordinary and red phosphorus. The variety of these isomeric states of a given element does not surpass that which exists between the isomeric states of a given liquid hydrocarbon such as the states of the carbide $C_{20}H_{16}$ —terebenthene, citrene, terebene. Neither does it surpass that which exists between the various polymers, liquid or solid, of a given carbide in different states of condensation, such as $C_{20}H_{16}$. In fact, all these carbides possess nearly the same specific heat.

"Such also are the differences which exist between the several graphites, whether the several graphites represent the manifold isomeric states of a given, equally condensed carbon, or whether they correspond to the several condensations of that element. Similar remarks apply in general to amorphous carbons. Here, then, we have examples of a certain species of isomerism and polymerism which does not change the specific heat appreciably.

"On the other hand, the comparative study of amorphous carbons, graphites and diamond reveals to us another mode of the condensation of matter more profound than that of ordinary polymerism, and communicating to the specific heat variations of the same order as those observed in passing from one elementary body to another."*

M. Moissan made a very careful research on the different varieties of carbon—amorphous, graphite and diamond—finally producing diamonds in his electric furnace.† His experiments show that "it is very difficult to obtain pure amorphous carbon."

"When carbon is obtained at ordinary temperatures and pressures, it appears in the form of an impalpable maroon-colored powder. It is very light, is not hard and is easily oxidized by nitric or chromic acid.

* *Ibid.*

† "Le Four Electrique," Paris, 1897, pages 53-203.

"This carbon always contains a certain amount of some elementary bodies—hydrogen, iodine, lead, zinc, etc.—with which it is associated during the reaction. To remove these impurities the carbon must be heated, that is to say, it must be polymerized."*

In his study of graphite Moissan examined a number of natural graphites, then proceeded to produce graphites in the electric furnace and describes three methods of performing that operation, which are briefly as follows:

(1) Amorphous carbon is heated to a very high temperature in the electric furnace, the conversion to graphite being effected by "simple elevation of temperature."

(2) An excess of carbon is dissolved in a metal or metalloid at a high temperature. The solvent is then allowed to cool down and the excess of carbon separates in the form of graphite.

(3) Carbon is dissolved or combined with another element and then thrown out as graphite by the introduction of some other body.

While lack of space forbids a description of all Moissan's experiments, typical examples illustrating the different methods may be noted.

(1) "Sugar carbon, purified by chlorine and placed in a closed crucible, was heated for ten minutes by an arc of 350 amperes and 70 volts. The appearance of the carbon is sensibly the same as before the experiment; however, its color has become grayer. * * * At the third treatment with the oxidizing mixture (potassium chlorate and nitric acid) it was transformed into pale yellow graphitic oxide.†

(2) "When aluminum is heated for five or six minutes in the electric furnace (350 amperes and 70 volts) in the presence of sugar carbon or simply in a carbon crucible, the metal carburizes and on cooling a residue, showing a yellow crystalline fracture and containing aluminum carbide, C_3Al_4 , is obtained. If it is heated for ten or twelve minutes, the aluminum carbide volatilizes partially and there remains a

* *Ibid.*, p. 69.

† *Ibid.*, p. 86.

brittle, porous, gray substance covered with crystals of graphite. The latter is separated by treatment with hydrochloric acid, then purified by sulphuric and hydrofluoric acids. Finally it appears in groups of very brilliant little crystals, sometimes showing some black filaments. Its density is 2.11. On the first treatment with the oxidizing mixture the graphite swells up, and on the second the smallest fragments are completely transformed into graphitic oxide."*

(3) "We started out with a gray cast-iron from Saint-Chamond, which contained 3.18 per cent. total carbon and 0.5 per cent. scorix. (In the analysis of iron, the mixture of the different varieties of carbon is separated by chlorine or mercuric chloride. The residue is burnt in oxygen and we give the name scorix to the ash which remains.)

"Ten grams of the cast-iron were placed in a porcelain boat lined with 2.3 grams of boron. The whole was heated strongly in a porcelain tube filled with dry hydrogen and placed in a reverberatory furnace. After the experiment a well fused residue, covered with a black layer composed entirely of graphite, was found in the boat."†

Moissan experimented with several elements in the production of graphite by the method of different solubilities at high and low temperatures, and the experiment with silicon is of especial interest, in view of the history of the Acheson method of producing graphite.

"When fused silicon is heated in a blast furnace it dissolves carbon, which it finally gives up in the form of graphite—clear crystalline plates of a brilliant black color and yielding a yellow graphitic oxide.

"At the temperature of the electric furnace silicon no longer yields graphite; it produces crystalline carbide of silicon."‡

Moissan's "Study of Carbon Vapor" is also worthy of note in this connection.

"Hitherto the formation of the vapor of carbon has not

* *Ibid.*, p. 88.

† *Ibid.*, p. 93.

‡ *Ibid.*, p. 92.

been demonstrated except in the electric arc, either by spectral analysis or by M. Berthelot's beautiful synthesis of acetylene.

"The existence of this vaporization outside the arc may be demonstrated in the following fashion: If a carbon tube, having an interior diameter of about 2 centimeters, is placed in an electric furnace made of lime, and heated by a powerful arc of 2,000 amperes and 80 volts, the interior of the tube is seen to be rapidly filled with a very light, black lining produced by the condensation of the carbon vapor.

"The carbon vapor may be made visible by placing a boat containing crystalline silicon in the middle of the strongly heated carbon tube. The silicon is then seen to fuse, to enter into ebullition, and as its vapor rises it meets the carbon vapor which descends from the upper part of the tube under the heat of the arc. There is produced between the boat and the tube a network of fine needles of silicon carbide. This crystalline and transparent compound is formed by the direct union of the two vapors."*

Certain natural graphites have a peculiar property of swelling up when treated with nitric acid and then heated to a temperature of about 200°. Moissan investigated this phenomenon and found that he could produce these swelling graphites in the electric furnace. He also made some experiments which seem to show that the swelling is caused by a rapid evolution of gas contained in the graphite.

Moissan's conclusions are as follows:

"According to M. Berthelot's definition we shall give the name graphite to the usually crystalline variety of carbon of which the density is about 2.2 and which yields a clearly characteristic graphitic oxide on treatment with the oxidizing mixture of potassium chlorate and nitric acid.

"Graphites are found on the surface of the earth and in certain meteorites. They may be divided, as M. Luzi recommends, into swelling and non-swelling graphites.

"The graphites obtained in the electric furnace by simple elevation of temperature are not swelling graphites.

* *Ibid.*, p. 159.

"On the other hand, all those which are obtained in a liquid metal at a high temperature, either by difference in solubility or by simple chemical reaction, have the property of swelling readily. This swelling graphite is very easily prepared in the electrical furnace by boiling platinum in a carbon crucible.

"The swelling of this variety of graphite should be attributed to a rapid evolution of gas.

"Artificial graphites may be amorphous or crystalline. Their density varies between 2 and 2.25. Their temperature of combustion in oxygen is about 660°.

"When they are pure they contain no hydrogen.

"A graphite obtained in the electric furnace, treated with no reagent and previously heated in a vacuum does not yield any water when burned in oxygen. On the other hand, ordinary cast-iron, treated with dilute acids, yields hydrogenous and oxygenous compounds which are indestructible at a red heat.

"When a graphite is prepared in the electric furnace its resistance to oxidation is proportional to the elevation of the temperature to which it has been brought.

"A graphite that is easily attacked, like Ceylon graphite, may be made more difficult of attack by heating strongly. This fact establishes the existence of many varieties of graphite analogous to the different varieties of amorphous carbons."*

In 1893 Girard and Street, in a lecture before the Société Internationale des Électriciens, describe a furnace which may be used for the conversion of carbon into graphite. The method consists in causing an arc or series of arcs to play over the surface of the carbon that is to be converted into graphite. It is stated that 85 per cent. of the carbon is transformed into graphite by this process.†

In 1891 Mr. E. G. Acheson, while attempting to obtain a hard crystalline form of carbon, discovered the new compound silicon carbide, now well known as an abrasive under

* *Ibid.*, p. 110, 111.

† Becker; *Manuel d'Electro-Chimie*, p. 449-458.

the name carborundum. Recognizing at once the valuable properties of this new compound, Acheson rapidly developed its manufacture and designed a new form of furnace for this purpose. The furnace was a brick box with an open top and carried carbon terminals at either end. In operating the furnace it was filled with a mixture of sand and coke, and the terminals electrically connected by means of a granular carbon core through which the current passed, heating it to such a high temperature that the carbon in the surrounding mixture reduced the silica and formed silicon carbide. After operating these furnaces Acheson usually found a layer of brilliant graphite lying between the core and the crystalline carborundum, and examination showed that this was formed by the decomposition of the silicon carbide. The temperature of the core, other things being equal, is a function of its sectional area, and hence if this happens to be somewhat smaller than usual the temperature will be proportionately higher and the silicon carbide in immediate contact with the core will be decomposed, the silicon being vaporized and the carbon left behind as graphite. The granular carbon, usually coke, composing the core of the furnace, also showed change, for the grains became softer and would mark paper like a pencil, left a brilliant polished surface on rubbing, were good conductors of heat and electricity and were almost chemically pure, containing only about 0.2 per cent. of ash. Sometimes petroleum coke was used to form a core, but that material did not yield a carbon, having all the clear characteristics of graphite. The granular carbon that had already been used as a core in a carborundum furnace was known as "old core" and was of much value, owing to its low electrical resistance, for if it was used to form the core of the next furnace the latter could be brought to its working temperature in a very short time. Acheson found that no matter how often this granular carbon was used as a core no further appreciable change in its properties occurred after the first time. Careful examination of the grains of the old core showed Acheson that these were by no means homogeneous, some being dull black in color and nearly as hard as the

original coke grains, while others had a brilliant metallic luster and could be cut with a knife like a piece of cheese. Further observation showed that the relative quantities of the dull, hard grains and the brilliant soft variety depended upon the coke used in making the core, and that the results obtained with different cokes depended upon the ash content. Combining these observations with those on the decomposition of silicon carbide, Acheson concluded that a general method for the production of graphite might be found in the formation and decomposition of carbides. The experiments undertaken to test this theory resulted in a patent on the "Manufacture of Graphite," in which Mr. Acheson says:

"I have also discovered, that in order to produce pure graphite from carbonaceous materials there is an indirect conversion, and that the act of formation of the graphite is more in the nature of an act of dissociation of the carbon from its combination with other materials than a conversion of the ordinary carbon into graphite, and that as a preliminary step the carbon has to be combined chemically with some other material. Thus I have found that if the carbonaceous material or carbon used in the process contains a considerable proportion of mineral matter, or if it is mixed with a certain proportion of oxide or oxides such as silica, clay, alumina, magnesia, lime or oxide of iron, the yield of graphite is enormously increased and the product is more satisfactory."*

An experiment which demonstrated the effect of carbide formation very clearly was the following: Two carbon rods, one composed of very pure lampblack carbon and containing less than 0.2 per cent. of ash, the other made of petroleum coke carbon which had been intimately mixed with a certain amount of ferric oxide, were heated side by side in an electric furnace. At the end of the experiment the rod that had contained the iron was found to be graphitic; could be easily cut with a knife, took a beautiful metallic luster on rubbing and would mark paper like an ordinary pencil. The pure

* U. S. Patent, 568,323, September 29, 1896.

carbon rod showed little change, was dull black in color, nearly as hard as before heating, and would not leave a mark on paper. One end of this carbon rod, however, was clearly graphite from the fact that it had been exposed to the action of vapors of carbide-forming elements. These vapors had even penetrated to a certain depth in the carbon rod, and in so far as this had occurred the rod showed a brilliant graphitic appearance, was soft, etc. This experiment will be referred to again in discussing M. Berthelot's researches.

It might be supposed that the production of graphite in the manner described above would necessitate the mixture of carbon and carbide-forming material in proportions such that the carbon present would be completely satisfied. Acheson's experiments showed, however, that the desired result could be obtained by a very much smaller percentage of the carbide-forming element, which apparently has the power of acting on successive quantities of carbon.

Having finished his preliminary experiments, Mr. Acheson formed a company for working his process of making graphite, and began to produce it on a commercial scale. The furnaces used in the Acheson process for making graphite electrodes and graphite commercially are very similar in outward appearance and magnitude to those used in Acheson's process for making carborundum. They are built of brick, in the form of a long, narrow trough, lined with some suitable refractory material. In making graphite electrodes the latter are manufactured of petroleum coke and pitch, like an ordinary carbon, such as is used in arc lights; but a certain amount of some carbide-forming material, such as silica or iron oxide, is introduced. The electrodes are baked in the usual way and are then ready for graphitization. To perform this work they are placed in a furnace and heated to a temperature above that of the volatilization of such bodies as iron, aluminum and silicon. That the temperature used in the Acheson furnaces is well above this point may easily be demonstrated, as the bodies above named are condensed in the form of their oxides outside the furnace.

In manufacturing graphite for other purposes, such as crucibles, paint, stove polish, etc., anthracite coal is usually employed. Having found a process for making graphite, Acheson next set to work to find a natural carbonaceous substance which would yield a graphite suitable for commercial purposes. He experimented with a great many materials, and finally discovered that anthracite coal gave the most satisfactory results. The furnace is filled with anthracite coal, through the center of which runs a core composed of carbon rods which connect the terminals of the furnace electrically. When cold, anthracite coal is a very poor conductor of electricity, hence the necessity for the core, which acts as a conductor and heats the surrounding anthracite when the furnace is started. Finally, the whole mass is raised to a very high temperature and converted into graphite.

Careful study of the products of the Acheson process has shown that, according to Berthelot's definition, the conversion of the amorphous carbon into graphite is complete, for the oxidizing mixture of nitric acid and potassium chlorate does not produce the least trace of the brown soluble body, characteristic of amorphous carbon, but yields only graphitic oxide.*

The density is increased considerably by the conversion of amorphous carbon into graphite:

Mean value of densities of six electrodes before graphitizing . .	1.90
Mean value of densities of the same after graphitizing	2.19

The electrical conductivity of the carbon is greatly increased by conversion into graphite, as is shown by the following results obtained by Mr. P. M. Lincoln, Resident Electrical Engineer of the Niagara Falls Power Company:

Resistance of 1 cubic inch of amorphous carbon electrode	0.00124 ohm.
Resistance of 1 cubic inch of graphite electrode	0.000320 ohm.

The purity of the graphitized carbon is greater than that of the amorphous from which it is made, for a greater or

* *Journal of the Society of Chemical Industry*, May, 1901.

less quantity of the contained impurities is volatilized, the final purity depending on the temperature to which the carbon has been raised and the time expended in heating. A specimen of anthracite coal was analyzed and found to contain 5.783 per cent. of ash. After prolonged heating and conversion into graphite the latter was found to contain only 0.033 per cent. of ash. Dr. Foerster, of the Dresden Technische Hochschule, has shown the remarkable resistance of Acheson graphite to disintegration in certain electrolytes.*

In some early experiments on the reduction of oxides by carbons, Dr. W. Borchers used an electric furnace which had for terminals two relatively large carbons connected to each other by a carbon rod of much smaller diameter. The small rod was highly heated by the passage of the current and was surrounded with the mixture of oxide and carbon on which he wished to make experiments. Like Despretz, Borchers found that when, in manipulating the terminal carbons, he applied pressure to the ends of the small highly heated rod it bent, and that on cooling it assumed a hard crystalline state. He found that the greater the impurities the lower the temperature at which the rods bent and the harder they were on cooling; also that substances which form alloys or decomposable compounds with carbon further its crystallization. Finally he describes an apparatus with which he believes valuable results might be obtained along the lines of his experiments.†

We may notice briefly a patent granted to Mr. H. Y. Castner in 1896 for an "Anode for Electrolytic Processes," in which is described a process for heating carbon electrodes by means of electricity to a very high temperature, with the result that a "graphite-like form of carbon is produced." It might be supposed that Castner's electrode was an anticipation of the Acheson graphite electrode were it not that Castner states that after treatment the electrode "will be found to be of decreased density." The Acheson

* *Zeitschrift für angewandte Chemie*, June 25, 1901.

† *Zeitschrift für Elektrochemie*, March 20, 1897.

graphite electrode, being actually converted into graphite, has a considerably higher density than the amorphous carbon of which it is made. In describing his process Castner also states that the temperature produced is such that "the carbon will give off the more inflammable material it contains." We may conclude, therefore, that Castner's process was nothing more than the electrical baking of carbon anodes.*

September 2, 1901, a German Patent granted to John Rudolphs and Johannes Härden, of Stockholm, was published. The specification for this patent describes a "process of obtaining graphite from carbon by means of electrical current." Attention is called to the fact that heretofore carbon has been converted into graphite by heating alone, care being taken to avoid oxidation during the process. The inventors propose to graphitize carbon by the simultaneous action of a high tension alternating current of high frequency, and a heating current of the usual kind. It is claimed that "the conversion of the carbon to graphite proceeds far more rapidly than by electrical heating alone; furthermore, experiments have shown that by means of this invention it is possible to graphitize much larger carbon pieces than is possible by known methods. This advantage may rest upon the fact that the high-tension alternating currents of high frequency produce very rapid ether-vibrations, which seem capable of favorably influencing the molecular alterations of the carbon pieces undergoing treatment.

* * * * *

"With the object of preventing the combustion of the carbon pieces to be treated, it is advisable to conduct the operation in an exhausted chamber or in the presence of inert gases in order to prevent, according to known methods, access of air to the glowing carbon."

Finally the following claim is made in the patent:

"Process of obtaining graphite from carbon by means of electric currents, characterized by the fact that a low-tension

* U. S. Patent 572,472, December, 1896.

sion heating current either in the form of a direct current or of an alternating current of low frequency (about 25 to 100 alternations per second), and a high-tension alternating current of high frequency (at least 50,000 alternations per second), are permitted to act simultaneously upon the carbon." *

This review of the more important work done on the production of graphite makes it clear that the various experimenters are by no means in agreement as regards the results they have obtained. Despretz in his experiments was endeavoring to show that carbon could be fused, welded and volatilized and thought he had done so. Moissan, however, in his experiments never found any sign of fusion, and concludes that vaporization occurs without previous fusion. In some of his experiments, at least, Despretz probably mistook the formation of fusible carbides for fusion of carbon. If a carbon rod is thoroughly impregnated with iron oxide and then heated electrically to a temperature somewhat below that of the volatilization of iron it will be found to be covered with little fused globules having a brilliant black metallic luster, and leaving a mark on paper like graphite. Examination of these globules proves that they are composed of iron intimately mixed with graphite, which has been formed by the method of "different solubilities" and not by fusion of the carbon as Despretz supposed. It is difficult to offer any explanation of Despretz's experiment with the anthracite which "spread out on the crucible like a piece of black glass." In the commercial manufacture of graphite, hundreds of tons of anthracite have been completely converted into graphite, but no phenomenon like this has ever been observed. The ash in anthracite coal is usually very evenly distributed, as may be seen by burning a lump of the coal; but it is not uncommon to find a very large excess of ash in part of a specimen that otherwise contains a low percentage. It is possible that the anthracite used by Despretz contained very little ash as a whole, but that the particular piece taken in this experiment was

* German Patent No. 123,692, Class 121, February 28, 1900.

very impure. Equally remarkable is the experiment where the carbon rods were impregnated with silica which was volatilized without producing any change in the carbon. As Despretz was looking for the fusion of carbon he may have overlooked other changes in its properties. Despretz's conclusion that any carbon becomes proportionately softer as it is heated for a long time to a high temperature is incorrect. Take, for example, the ordinary manufactured carbon, the hardness of which is increased by prolonged baking at a very high temperature, or take some forms of anthracite coal, which may be so greatly hardened by heating for some time to a high temperature out of contact with air that they will readily scratch glass.

Berthelot's researches bring out very clearly the peculiar properties of the different forms of carbon and the relations existing between the different states of the same element, thus lessening to a great extent the apparent incongruity of the results obtained in the work of different experimenters. Some of these incongruities are due to the ambiguity in the use of the word graphite. Berthelot's definition of graphite as that form of carbon which on oxidation at low temperatures yields graphitic oxide is perfectly satisfactory from the chemical point of view, but it is not always satisfactory in practice; for example, as Berthelot himself points out, some forms of carbon which will come under his definition will not mark paper. Reference has already been made to one of Acheson's experiments in which two carbon rods, one containing metallic oxide and the other being pure, were heated side by side in an electric furnace. Subsequent examination showed that both carbons could be converted into graphitic oxide, and hence that they both were graphites according to Berthelot's definition. Nevertheless, the carbon which had originally contained practically no metallic impurities had none of those properties which are ordinarily recognized as characteristic of graphite. Incidentally, it is worth noting that an experiment on the relative incombustibility of the carbons showed that the carbon which had originally been pure oxidized nearly 100 per cent. more rapidly than the other carbon. The conclusion to be drawn

from a comparison of Berthelot's and Acheson's researches seems to be that while all true graphites yield graphitic oxide, all bodies yielding that compound are not necessarily graphites suitable for practical purposes. In view of the fact that various kinds of hard and soft graphites produced by artificial means are now being put on the market, and that varieties of amorphous carbon (notably retort carbon) are also sold under the name of graphite, it would seem to be advisable to revise the nomenclature of carbons, reducing it to a more rational and practical form that will be free from all such ambiguities.

The experiments on the separation of carbon from the carbides of boron, iron and manganese are particularly interesting, showing, as they do, that in order to produce graphite the method of decomposing the carbides is by no means indifferent. The boron carbide alone yielded graphite by Berthelot's method of separation, while Acheson's method of decomposing the same carbides produced graphite in every case.

So far as Berthelot's experiments went amorphous carbon is not converted into graphite by simple elevation of temperature. In order to bring about this transformation the presence of oxygen, or some other body, seems to be necessary, or an electrical influence must be present. In the case of arc-light carbons special stress is laid on the fact that graphite is produced to an appreciable amount on the negative pole only, and the examination of Despretz's capsules showed that they were converted into graphite "at the negative pole."

The most interesting of Moissan's methods of transforming amorphous carbon into graphite, as compared with the commercial method, is the conversion by "simple elevation of temperature." While his investigations show clearly that heat has a most distinct effect in bringing about the polymerization of both carbon and graphite, yet, in view of Acheson's work on the remarkable part played by various carbide-forming substances in effecting the transformation of amorphous carbon into graphite, none of Moissan's experiments is rigidly conclusive in demonstrating that the

change is effected solely by elevation of temperature. Even placing the specimen of carbon in a covered carbon crucible does not necessarily protect it from the action of the metallic vapors which must invariably have been present in Moissan's furnace, since at high temperatures the densest carbons are very porous. Moissan refers to this porosity in the description of his tubular electric furnace,* and in certain experiments made at the works of the Acheson Graphite Company, very dense carbons at high temperatures were found to be astonishingly porous to metallic vapors.

The experiment cited as proving the vaporization of carbon outside the arc is difficult to understand when taken in connection with Acheson's production of graphite by the decomposition of silicon carbide. In Moissan's experiment, silicon was boiled and its vapor combined with "the carbon which descends from the upper part of the tube," and formed silicon carbide. Acheson placed a mass of silicon carbide in an electric furnace and heated it to a high temperature, so high that the carbide was decomposed, the silicon being completely vaporized, while the carbon formed a graphite skeleton of the crystals, the angles of which were perfectly clear and sharp, showing that there had not been the smallest vaporization of the carbon. In the description of Moissan's experiment we are not told whether an inert gas was passed through the tube or that any special precautions were taken to avoid all possibility of the entrance of air during the heating. If this were not done, carbon monoxide gas would be formed, and in contact with a relatively large mass of silicon vapor would probably be reduced with the formation of silicon carbide crystals and silica in the form of vapor. The silica vapor in contact with a large excess of carbon (the walls of the tube and the carbon boat) would in turn be reduced, silicon carbide and carbon monoxide being formed. This explanation is possible, in view of the fact that at very high temperatures the direction of the reducing action seems to depend largely on the relative masses of the reacting bodies. As for the light black lining

* "Le Four Electrique," p. 24.

of the tube "produced by condensation of the carbon vapor," that could be produced by the disintegrating action of the oxygen of the air playing upon the walls of the tube. Some such action seems more probable than the supposition of vaporization, since the latter would require the condition that there should be no drop in temperature between the outside of the tube, on which the arc is playing, and the inside.

Here attention must be called to an interesting article by Clinton Paul Townsend, in which he discusses the work of the various experimenters, and finally suggests that their results may be reconciled by the hypothesis that "the preliminary ionization of the carbon is essential to the production of graphite. For it will be noted that when Moissan speaks of 'elevation of temperature' he means the heat of the electric arc, whereas Acheson and Borchers refer to the heat developed in a carbon resistance. In the former case conditions favorable to the ionization of the carbon are present, while in the latter such effects are excluded. * * *

"Other of the observations before referred to tend to confirm the view that the production of graphite is due to more than the simple heat-effect of the current. Berthelot's supposition that the mixture of the two forms of carbon, which results from the passage of an electric discharge through hydrocarbons and cyanogen, is due to the joint action of heat and electricity, appears eminently probable. * * * If we re-examine the work of Despretz we find that whenever the arc was used the transformation to graphite was readily accomplished, even though the ash-content of the carbon were only one part in 7,000; but when the carbon, as a filament, was directly included in the circuit, the results are less positive, and the production of graphite seems to follow either the presence of a large admixture of ash, or the rupture of the filament."*

The process described by Rudolphs and Härden in their patent is interesting, but we have not been able to find any more details of the method than those given in the patent.

* *Electrical World and Engineer*, April 6, 1901.

The results obtained by Borchers in his experiments tend to show that carbide-forming substances "further the crystallization of carbon," and so far confirm Acheson's observations on the important part played by these bodies in passing from one allotropic form of carbon to another; but they do not form good ground for the claim of priority advanced by Borchers,* for they were published long after Acheson's results were made known in his patents.

It may be well to note here an extraordinary claim put forward by Dr. Otto Mühlhaeuser† that he is the original discoverer of the fact that graphite is produced by the decomposition of silicon carbide. Mühlhaeuser was employed for a few months as chemist of the Carborundum Company, but the records show that Mr. Acheson's application for the carborundum patent was made before Mühlhaeuser even arrived in America, and the specifications show that Mr. Acheson was then familiar with the production of graphite in this way.‡

TO PREVENT THE FREEZING OF GAS-PIPES.

A simple but effective device for preventing the freezing of gas-pipes is described in the *Illustrirte Zeitung für Blechindustrie*. It consists merely in the insertion of a wider piece of pipe just where the conduit issues from the ground or wall. For a conduit of a diameter from $\frac{3}{8}$ to $\frac{1}{2}$ of an inch a length of from 20 centimeters to 30 centimeters of a pipe 1 inch in diameter suffices. The deposition of the water particles contained in the gas, which on leaving the works have a temperature of about 50° F., naturally takes place just where the gas is subjected to the most abrupt change of temperature, *i.e.*, on its issue from the ground. If the external temperature is sufficiently low, the deposited water immediately congeals and clogs the conduit. As soon as the gas has acquired the temperature of the conduit the deposition of water and congealing cease, and this is said to be the case a short distance beyond the first cooling point. Therefore, there should be no congealing beyond the inserted wider piece, and this piece is wide enough to accommodate a thick ice-crust and to still leave a free passage for the gas. As a matter of fact, the principle of this new method is already employed in street lamps, and with success.—*Scientific American*.

* *Zeitschrift für Elektrochemie*, September, 1899.

The Mineral Industry, vol. 8, p. 678.

† *Chemiker Zeitung*, No. 31, vol. 26.

‡ U. S. Patent 492,767, February 28, 1893.

CHEMICAL SECTION.

*Stated Meeting, held Thursday, February 27, 1902.***The Analytical Methods for Carbohydrates as Applied
to Foods and Feeding Stuffs.**

BY WILLIAM H. KRUG,
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The analysis of a food or a feeding stuff has for its object either a determination of the nutritive value of the material or the detection of an adulteration. Of these the latter is probably the most important, since it is of direct interest to the public at large and is intimately connected with the general health and moral status of a people. The adulteration of food may be broadly classified as that which is merely a financial fraud and consists of the partial or total substitution of an article innocuous in itself but sufficiently lower in price to induce the sophistication, and that which by its use becomes a direct menace to the health of the purchaser. Both forms of adulteration are extensively practised, and it is a natural sequence that food-chemistry has rapidly become a special branch and has experienced a remarkable development in recent years. The results of the studies of many able investigators are manifested in the strict food laws adopted by almost all European countries and in the analytical methods which are to-day used and which, while in some instances not absolutely reliable, are still found to be generally satisfactory, and are accepted by the courts in cases of prosecution for adulteration.

Before entering into a discussion of the application of the results obtained in the determination of the carbohydrates in foods it may be well to say a few words concerning the general analytical methods. With few exceptions, the methods employed for the determination of the water-soluble carbohydrates are either physical (polariscopic methods) or depend upon the reducing power of the sugar when brought

in contact with a boiling alkaline copper solution. The polariscopic methods are based on the property possessed by all sugars to a greater or less degree of rotating a polarized ray of light, and a number of instruments have been devised to measure the degree of rotation. The one now most commonly used has been designed by Schmidt and Haensch, and is constructed in such a manner that a solution of pure sucrose containing 26.048 grams in 100 Mohr's cubic centimeters when observed in a 200 millimeter tube at 17.5° C. will read exactly 100. This weight corresponds to 25.9872 grams in 100 true cubic centimeters, and the International Commission for uniform methods of sugar analysis at the Paris meeting in 1900 decided to adopt 26 grams in 100 true cubic centimeters at 20° as the normal weight. The polariscopic methods are naturally the most rapid and convenient and are generally used when only one sugar is present or the other optically active substances in the solution are such that they can be readily removed. They find extensive application in the analysis of sugars and sugar products, milk, milk sugar, honeys, etc. Sucrose is almost exclusively determined by means of the polariscope, and when invert sugar is present, as in low grade sugars, the chemist uses the Clerget method, which depends on the polariscopic reading before and after inversion with hydrochloric acid.

Dextrose may also be determined by means of the polariscope; but it must be remembered that the solution, when first prepared, exhibits birotation, which can, however, be destroyed by heating to 100° C. for fifteen minutes.

The quantitative methods, both volumetric and gravimetric, which have been proposed and are to-day used for the determination of the sugars which have the property of reducing an alkaline copper solution, are so varied and numerous and are, as a whole, so well known that I do not believe it necessary to dwell on them in detail. Exact methods are now adopted for all of the more common reducing sugars, such as dextrose, levulose, invert-sugar, maltose, lactose, etc., and when these sugars occur alone or in mixtures of not more than two, a satisfactory determina-

tion is not difficult. Thus the determination of invert-sugar and cane-sugar when present in a solution has been thoroughly studied, it being found that the sucrose exercises a marked influence on the reducing power of the invert-sugar. The increase in reduction produced has been determined and tables for the correction of the results have been worked out by Meissl, Wein and Herzfeld. Soxhlet found that this increase, due to the presence of the sucrose, only took place when an excess of the alkaline copper solution was used, and has described a volumetric method which yields direct results.

Similarly it is possible to determine two reducing sugars, such as invert-sugar and dextrose, when present in the same solution, by utilizing their property of reducing Fehling's copper and Sacchse's mercury - reagent in different but constant proportions, when the determinations are made under the same conditions. Extreme difficulties however are encountered when the chemist is required to examine complex mixtures, such as infant foods, malt extracts, etc., and in most cases of this kind an exact quantitative separation of the individual carbohydrates is practically an impossibility. It may be of interest to mention a method which can be used with such materials which, although yielding only approximate results, is nevertheless frequently applied and enables a determination of the sucrose, dextrose, levulose, maltose, isomaltose and dextrin in a mixture. The determinations made are as follows:

(1) The reduction with Fehling's solution.

(a) in an aqueous solution,

(b) after inversion with invertin at (50° – 55° C.),

(c) in the solution remaining after fermentation with a suitable wine yeast that does not attack maltose,

(d) in the solution obtained according to c after inversion with hydrochloric acid.

(2) The dextrans by precipitation with alcohol. These data are then used in the following manner:

(a) The difference of *a* and *b* = sucrose.

(b) The difference of *a* and *c* = dextrose and levulose.

(c) The difference of *d* and *c* = maltose and isomaltose.

In connection with this method the polariscopic results often furnish valuable data.

All foods and feeding stuffs contain carbohydrates either soluble or insoluble in water. The former include sucrose, dextrose, levulose, invert-sugar, lactose, dextrans, etc., and are separated by extracting the material with water. The aqueous extract may be evaporated to dryness, the residue less ash representing the total "water-soluble carbohydrates," or the carbohydrates may be separately determined, when it is customary to obtain the reducing power before and after inversion, the first result being stated as "reducing sugar estimated as dextrose" while the sucrose is estimated by means of the difference between the first and second result. When the nature of the sugars present is known, special methods are naturally applied, whereby more accurate data are obtained.

Dextrin, when present in the aqueous solution, is removed and determined by evaporating an aliquot portion to a syrupy consistency and precipitating with an excess of absolute alcohol. The precipitate is dissolved in water and inverted with hydrochloric acid, the dextrose being determined in the final solution.

It is only in recent years that much attention has been given to the methods used in determining the insoluble carbohydrates in foods and feeding stuffs. Previous to this time it was customary, especially with the feeding stuffs, to group all the carbohydrates under the term "nitrogen-free extract," which represented the difference between the total and the sum of the protein, fat, crude fiber, moisture and ash. This method is even now generally followed with feeding stuffs, it being assumed that the carbohydrates all have approximately the same nutritive value. The most important polysaccharids present in foods are starch, the pentosans and galactan. The former two occur in varying quantities in all foods, and the galactan more especially in seeds, where it appears to exercise the function of a reserve-substance.

All of the polysaccharids are hydrolyzed, when treated with an acid, and yield sugar. Thus, the ultimate product

from starch is dextrose; from the pentosans, the pentoses, and from galactan, galactose. The determination of the starch depends on its final conversion into dextrose, and it is evident that in the presence of other polysaccharids a direct treatment with acids will yield an erroneous result. The material must therefore be treated in such a manner as not to attack the other constituents, and this is accomplished by gelatinizing the starch and then saccharifying it by means of a diastase solution. The insoluble portion is removed by filtration, the filtrate inverted with hydrochloric acid and the dextrose determined gravimetrically and calculated to starch by means of the factor 0.90.

The term "pentosans" includes both xylan and araban and is used when the identity of the carbohydrate is not known. Feeding stuffs contain variable amounts of pentosans, and digestion experiments have shown that they possess a definite nutritive value. Thus, Lindsey and Holland (Massachusetts State Report, 1894, p. 175) found them to be practically as digestible as any of the other groups of fodder-constituents, the digestibility varying from 60 to 80 per cent. Stone and Jones (Maine Report, 1893) stated the average digestibility to be 58.2 per cent. The importance of these figures will be appreciated in view of the fact that hay contains from 15 to 20 per cent., wheat-bran from 15 to 30 per cent., and brewers' grain from 20 to 30 per cent.—all being important cattle-foods.

The quantitative method used for the estimation of the pentosans depends on their conversion into furfuraldehyde when distilled with 12 per cent. hydrochloric acid. The furfuraldehyde in the distillate is precipitated by the addition of a sufficient quantity of phloroglucol, the precipitate consisting of phloroglucid, a condensation product of unknown composition. This is collected, dried and weighed. The factors for conversion of the phloroglucid into pentosans or pentoses are based on determinations made with known quantities of the pure sugars and of furfuraldehyde.

Concerning the nutritive value of galactan little appears to be known. This polysaccharid is widely distributed in the plant kingdom, but occurs principally in seeds. Very

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little is found in cereals and fodders, while clover seed contains as much as 5 per cent. and lupine seed as much as 12 to 15 per cent.

The quantitative method for the estimation of galactan is based on its eventual conversion into mucic acid. The material is treated with nitric acid of 1.15 specific gravity, which primarily hydrolyzes the galactan with the formation of galactose and then oxidizes this sugar to mucic acid. The magma is digested with ammonia to form the soluble ammonium mucate, which is removed by filtration, and the mucic acid, precipitated by the addition of nitric acid, washed, dried and weighed. It is converted into galactose by the factor 1.33, and this multiplied by 0.9 gives galactan.

The analysis of feeding stuffs also includes a determination of the crude fiber, which is supposed to represent the indigestible portion. The method used depends on a consecutive digestion of the material with boiling 1.25 per cent. sulphuric acid and 1.25 per cent. sodium hydroxid solution whereby all carbohydrates, fats and protein are supposed to be removed. It has been shown, however, that the fiber thus obtained still contains appreciable quantities of hydrolyzable carbohydrates, notably pentosans, and it can therefore be only accepted as an approximate expression of the indigestible constituents, although sufficiently accurate in view of the fact that it is manifestly impossible to imitate the digestive processes except in an exceedingly rough manner.

When a more accurate determination of the cellulose is required it may be obtained by the chlorination method devised by Cross and Bevan.

Briefly stated, a complete analysis of a food or feeding stuff, in so far as the carbohydrates are concerned, will therefore consist (a) of the separation of the water-soluble carbohydrates, which are determined individually if needs be, or merely stated as sucrose and reducing sugar,

(b) of a determination of the starch,

(c) of a determination of the pentosan,

and (d) of a determination of the galactan.

Special methods of analysis will be described in connection with the food materials to which they are applied.

The nutritive value of a food depends essentially on three distinct constituents—the proteids, fats and carbohydrates. While it is impossible to express the food value in exact terms, owing to certain indefinite factors such as digestibility, individual idiosyncrasies, etc., we may still arrive at a general expression suitable for comparison by the adoption of tentative factors which König has determined by means of numerous nutrition and digestion experiments, and which are exhaustively discussed in his “*Chemie der menschlichen Nahrungs- und Genuss-mittel.*” These factors as at present used for human foods are:

- 1 gram carbohydrates = 1 nutritive unit.
- 1 gram fat = 3 nutritive units.
- 1 gram protein = 5 nutritive units.

The manner in which these factors are applied with the analysis of a food as a basis is best shown by an example. A kilo of meat is found to contain 200 grams protein, 60 grams fat and 2 grams carbohydrates. It will then contain:

200 grams protein	$\times 5 = 1000$
60 “ fat	$\times 3 = 180$
2 “ nitrogen-free extract	$\times 1 = 2$
	<hr style="width: 10%; margin: 0 auto;"/>
	1182 nutritive units.

If this kilo of meat costs 40 cents, the value of each nutritive unit will be .0339 cents. The application of these results obtained by the analysis of a food in the calculation of the amount of food necessary to supply the nutrition required by individuals engaged in various occupations, of army rations, suitable inexpensive daily meals, etc., is a subject of such magnitude that it cannot well be brought within the province of this paper. Articles bearing upon this field of research will be found in Elsner, “*Die Praxis des Chemikers;*” König, “*Die menschlichen Nahrungs- und Genuss-mittel,*” and the valuable series of bulletins containing the investigations of Prof. W. O. Atwater and issued by the office of Experiment Stations of the United States Department of Agriculture.

Voit's investigations may, however, be mentioned as indicating in general the quantity of carbohydrates required in the daily food of individuals. He arrives at the following figures:

	Protein. Grams.	Fat. Grams.	Carbohydrates. Grams.
Laborer, fair health, average work . . .	118	56	500
“ good “ “ “ . . .	137	72	352
“ “ “ hard “ . . .	137	173	352
Prisoner, little work	100	30-50	300-500
Old person, no work	70-80	30-50	300
Child, 6-15 years old	80	40	250

I have quoted the figures for protein and fat, as the data for carbohydrates would otherwise appear contradictory. The meals given to such persons can be judged with sufficient accuracy by using the figures as a basis, and suitable combinations of foods can be designed, as the average composition of all common foods is sufficiently well known. In cattle foods, the relative value of the carbohydrates, protein and fat, is chosen somewhat differently, it being:

Protein $\times 5 =$ nutritive units.

Fat $\times 5 =$ “ “

Nitrogen-free extract $\times 1 =$ “ “

Thus, if we have a cattle food costing \$1 per 100 pounds, and the analysis shows it to contain 15 per cent. protein, 5 per cent. fat and 25 per cent. nitrogen-free extract, the value of the nutritive unit will be calculated as follows:

$$\frac{100}{[(15 + 5) \times 5] + 25} = .8 \text{ cent.}$$

The Carbohydrates in Foods as a Basis for the Detection and Estimation of Adulteration.—There are probably few foods which suffer an adulteration in which an analysis with reference to the sugars or other carbohydrates is not indicated, and often absolutely necessary. In many cases the latter are directly used as an adulteration, and in others, the pure food is known by experience to contain a certain percentage of carbohydrates, the limits within which these constituents vary having been established, so that a quantitative determination frequently furnishes valuable indications. In discussing the practical application of the results

obtained and the judgment of the various foods, I have thought it best to treat the latter in classes. We have, so far, unfortunately, no federal law with appropriate food standards in this country, although various States have adopted certain regulations which naturally lack uniformity and, furthermore, cannot control interstate commerce. I have therefore been forced to draw freely from the German regulations and standards, with which the provisional analytical methods adopted at the last convention of the Association of Official Agricultural Chemists agree in the main points.

Meats and Meat Products.—The analysis of meat products, such as canned meat, sausages, chopped meat, etc., must take into consideration two possible methods of adulteration, which are the addition of horse-meat, or of starch or flour, the latter applying more specifically to canned goods and sausage. The use of horse-flesh is very commonly practised in France, Germany and Austria, although the dealers are supposed to declare such addition. While in no sense deleterious to health, these adulterations are clearly financial frauds. The detection of an addition of horse-flesh is difficult, and most of the methods proposed depend on the fact that this meat contains more glycogen than other meats. These methods will give fairly accurate results if the meat is absolutely fresh, but become practically valueless when the meat has been kept for some time, because the glycogen rapidly disappears after death, probably being converted into dextrose. A qualitative test* may be made by boiling the meat with an equal volume of water and testing the filtered broth with a few drops of a potassium iodid-iodin solution (two parts iodine, four parts potassium iodid and 100 parts water). In the presence of glycogen a dark-brown color is developed which disappears on cooling. When starch is present it should be precipitated by adding two volumes of glacial acetic acid. Niebel† considers all color tests to be merely confirmatory in connection with the

* Bräutigam and Edelmann, "Pharm. Centralbl.," 1893, 557.

† "Ztschr. Fleisch u. Milch-Hygiene," 1895, 86.

quantitative determination. Most of the quantitative methods are extremely tedious and the Mayrhofer method* is probably most convenient and, at the same time, sufficiently accurate.

A preliminary examination for starch should always be made by means of the microscope and iodine solution, and when this is absent, the glycogen may be determined as follows:

Fifty grams of the meat or sausage is treated with 8 per cent. alcoholic potassium hydroxid solution, diluted with warm 50 per cent. alcohol and the precipitate collected on a filter and washed with strong alcohol. The residue is dissolved in an aqueous potassium hydroxid solution, slightly acidified with acetic acid and mixed with an excess of alcohol. The precipitated glycogen is washed with alcohol and ether, dried and weighed. It must be a white amorphous powder containing neither nitrogen nor ash. The aqueous solution must have a white opalescence, must give a deep-red color-reaction with iodine and must not reduce Fehling's solution.

In the presence of starch, which is frequently added to canned meats and sausages, this method can, however, not be used, as the starch is also precipitated. With such materials the Niebel-Salkowski method† gives satisfactory results, although it is very tedious and time consuming. According to this method the meat is dissolved in a 1 per cent. aqueous potassium hydroxid solution, which is exactly neutralized. The proteids are removed by repeated treatments with Nessler's solution and the glycogen is precipitated in the filtrate by means of alcohol. As previously stated, the glycogen rapidly disappears from the fiber after death, and all these methods may yield negative results even when horse-meat is present. When such an addition is suspected, it is therefore always necessary to determine the reducing sugar by digesting a weighed portion of the meat with cold water and estimating the dextrose in the filtered

* "Bujard, Forschungsber." 1897, 47.

† "Ztschr. Fleisch u. Milch-Hygiene," 1891, 185.

extract in the usual manner. To this is added the dextrose equivalent to the glycogen found (10 glycogen—11 dextrose), and according to Niebel, the presence of horse-meat is proved when the total sugar exceeds 1 per cent. of the fat-free dry substance, the limit being based on numerous analyses of various meats, which have shown that absolutely fresh meat in which the action of the enzyme, which converts glycogen into dextrose has been arrested by immersion in boiling water, contains only traces of dextrose.

In no case should a determination of the glycogen or reducing sugar be accepted as sole proof of the addition of horse-flesh. It is at the most only corroborated evidence in connection with the other analytical data obtained.

Sausages are frequently adulterated by the addition of an excessive amount of starch or flour. This adulteration enables the manufacturer to use a poor grade of meat, as the gelatinization of the starch during cooking accomplishes the intimate combination of the constituents otherwise not attainable, and also permits the incorporation of a larger proportion of water without affecting the outward appearance of the product. This form of adulteration is primarily a financial fraud, which is the more serious when we consider that meat in this form is consumed more extensively by the poorer classes. The health of the consumer is furthermore endangered, as the large proportion of gelatinized starch present causes the product to deteriorate rapidly. A preliminary examination is in most cases sufficient and may be made with the microscope, using iodine, or by applying the reagent directly to a freshly cut surface. When a considerable quantity of the adulterant is present, as will be generally the case, the surface will be colored a deep blue wherever the iodine has penetrated. The isolated, hardly noticeable blue spots which, in the absence of added starch or flour, are due to the starch naturally present in the condiments, such as pepper, can in no case render the result doubtful.

The quantitative determination of the starch present, either as such or as flour, cannot be made by the diastase method, as has been recommended, since it has been found

that the final solution obtained contains some constituents derived from the meat which retard the precipitation of the cuprous oxid and thus lead to a low result. The exact nature of these compounds is not understood, but experiments made in the Bureau of Chemistry of the Department of Agriculture proved conclusively that when a known amount of starch was added to chopped meat it could never be fully recovered by this method. A modification of the Mayrhofer method for glycogen, reference to which was just made, can also be used for starch and appears to be satisfactory. Extreme accuracy is naturally not required, as such a sophistication, if practised at all, is carried to such an extent as to condemn the product even though a large error may accompany the analysis. In this connection it must not be forgotten that in some sections a small quantity of starch or flour is always mixed with sausages, this being in accordance with general practice and the demands of the consumers. While it is, therefore, impossible to establish an absolute limit for the amount of starch or flour in these foods, a certain arbitrary maximum must be fixed. In certain districts of Germany this is placed at 2 per cent., while in others no addition whatever is allowed. The starch which is present through the addition of condiments, such as pepper, pimento, etc., rarely exceeds 0.4 per cent., and therefore never endangers the reliability of the analysis.

Milk and Milk Products.—The determination of the milk sugar or lactose has little value, in so far as the detection of adulteration is concerned, and is therefore rarely required. The quantity of lactose in normal milk varies from 3.5 per cent. to 5.5 per cent., and with individual cows the variations are still greater, depending on different circumstances, such as race, method of feeding, lactation, general health, etc. Isolated cases are reported where skimmed milk has been adulterated by the addition of starch or flour, so as to impart a creamy appearance. When such an addition is suspected, a microscopical examination of the sediment is sufficient to detect the fraud and a quantitative analysis is not required. Skimmed milk is also adulterated occasionally by adding cane-sugar.

The sucrose can be determined by inverting it with some agent which does not attack the lactose.* Either citric acid or dilute hydrochloric acid can be used, the polarization being determined before and after the inversion. Another method,† which is frequently used by German chemists, also depends on inversion, but uses hydrochloric acid and prolongs the action of the acid until all the lactose is converted into invert-sugar. The amount of invert-sugar due to the lactose present is calculated and deducted from the total found. All of the gravimetric methods probably yield only approximate results, owing to the fact that the reducing power of a sugar is in general materially influenced by the presence of another sugar. When a determination of the total sugar shows a milk to contain more than 6 per cent., it may be declared adulterated. It is highly improbable, however, that this rather expensive form of sophistication is practised to any extent.

Condensed milk is prepared by the evaporation of normal milk to the required consistency with the addition of 25 to 50 per cent. of cane-sugar. In the ordinary routine of food inspection it is generally sufficient to calculate the total sugars by differences, but a complete analysis may occasionally be required when the lactose and sucrose can be determined with sufficient accuracy by the methods above described. The average of a number of analyses shows condensed milk to contain 16 per cent. lactose and 31 per cent. of sucrose.

Butter is very rarely adulterated by the addition of such materials as starch or flour. Glucose is frequently used as a preservative, especially in butter prepared for export trade, in which Crampton‡ reports as high as 10 per cent., and quite recently the chemist in charge of the dairy laboratory in the Bureau of Chemistry, U. S. Department of Agriculture, has found a number of samples adulterated in this manner, although the amount of glucose present in no case

* "Leffman and Beam, Food Analysis," page 228 et seq.

† "Bujard and Baier, Hilfsbuch für Nahrungsmittelchemiker," Ed. 2, p.

122.

‡ *Jour. Am. Chem. Soc.*, 1898, 207.

exceeded 4 per cent. These samples were all labeled butters — *i. e.*, butters which are prepared by mixing a number of shipments of different colors. To detect the addition of glucose the melted butter is shaken repeatedly with hot water and the reducing sugar determined in the water extract. It must be remembered, however, that normal, unsalted butter will contain as much as 1 per cent. of milk sugar.

Cheese is occasionally adulterated by the addition of flour, starch or ground potatoes. The microscopical examination readily detects such an adulteration, and may be made on the residue left after digesting the suspected sample with ammonium hydrate, in which cheese is almost completely soluble.

Flour and Breadstuffs.—It is very doubtful if flour is to-day adulterated to any extent. Previous to the passage of the Federal flour law the adulteration had assumed considerable proportions, especially with wheat flour intended for export trade. The substitution then consisted principally of corn-flour or cornstarch, the latter being sold for the purpose under the trade-name of "flourine." This form of adulteration became so extensive that it was sharply attacked by European officials and, as a natural sequence, caused a material decrease in the exports of American wheat flour.

The presence of a foreign flour in the sample under examination is most conveniently detected by means of the microscope, the form and size of the starch grains of each cereal being sufficiently characteristic to be recognized by the experienced microscopist. The addition of rye or maize flour to wheat flour can be shown by the Baumann method,* which depends on the property of wheat starch of gelatinizing completely when one gram of flour is shaken for two minutes with 10 cubic centimeters of a 1.8 per cent. potassium hydroxid solution. After partial neutralization of the alkali a drop of the mixture is examined with the microscope, when the rye or maize starch, if present, will be found practically intact. A number of qualitative color-tests have

* "Ztschr. für Untersuchung der Nahrungs- und Genuss-mittel," 1899, 28.

also been proposed. The presence of potato flour or wheat flour may be detected by rubbing the sample with water until a stiff paste is obtained, which is thinned with water and filtered. The filtrate, when tested with iodine, becomes deep blue when potato flour is present, while with pure wheat flour, only a yellow to orange is obtained. Buckwheat flour is frequently mixed with rice flour, and this may be detected by preparing a thin paste with water and adding a solution of calcium hydroxid. Pure buckwheat is colored dark green, changing to red on the addition of hydrochloric acid. Rice flour, similarly treated, gives a yellow color, which is destroyed by hydrochloric acid. A mixture of the two flours yields intermediate colors. All color-tests should be used very cautiously, however, when judging of an adulteration and should not of themselves be considered absolute proof.

The final decision should always be based on a careful microscopical examination. Even when no adulteration is present it is necessary to carefully observe the starch grains. They should be normal in size and appearance and shrunken grain, or grains which are swollen through the presence of an excess of moisture, should be absent, as these are proof of a deterioration in the quality of the flour. Flour which contains a considerable quantity of such starch will produce a bread prone to early decomposition, although a very thorough baking may prevent this.

The statements with reference to the examination of flour apply also to bread and the various breadstuffs. The detection of foreign flours is, however, attended with considerably more difficulty, as the starch grains suffer almost complete destruction during the process of baking, so that absolutely conclusive results can rarely be obtained.

Infant foods, most of which are mixtures of desiccated milk with flour in which the starch has been rendered partially soluble by treatment with steam and pressure, or the action of acids or diastase, are at present offered to the public in great variety. The chief claim made by the manufacturers of these foods is that they are easily digested and quickly assimilated. Their nutritive value depends mainly

on the percentage of soluble carbohydrates present, and the method of preparation should always be such as to carry this to the highest attainable point. The analysis of these foods includes a microscopic examination for unchanged starch, and a determination of the soluble and insoluble carbohydrates and preparations are frequently found which are flagrant deceptions, consisting merely of ordinary grades of flour. The soluble carbohydrates are generally determined by digesting the material, after removal of the fat, with 50 per cent. alcohol and determining the total solids in the filtered extract, the ash being deducted. The insoluble residue serves for the determination of the starch in the usual manner. No attempt is usually made to separate the soluble carbohydrates quantitatively, owing to the complex nature of the mixture. The great variety of materials used in the preparation of these foods makes it impossible to fix any definite standards as regards composition.

Sugars.—The extensive class of human foods whose nutritive value depends on the presence of sugar and which includes the various grades of refined sugar, syrups, molasses, maple sugar, honey and confectionery, is naturally one of the most important as regards the analytical methods used for the determination of the carbohydrates. One of the most important applications in this respect is the analysis of sugars, syrups and molasses imported into this country and subject to duty. The present tariff law imposes a duty of $\frac{9.5}{100}$ of a cent per pound on all sugars not above 16° Dutch standard in color, tank-bottoms, cane-syrups, melada, concentrated melada, concrete and concentrated molasses testing not above 75° polariscopic degrees and an additional $\frac{3.5}{100}$ of a cent for every degree above 75°, fractions of a degree being taxed proportionally. Refined sugars and sugars above 16° Dutch standard are taxed $1-\frac{9.5}{100}$ cents per pound. Molasses which polarizes above 40° and not above 56° pays a duty of 3 cents per gallon, and molasses which has a polarization above 56° of 6 cents per gallon. It is therefore evident that extreme accuracy in the sampling and analysis of the importations is highly important, and detailed regulations concerning the method to be pur-

sued have been issued by the Treasury Department. With high grade sugars, either beet or cane, a direct polarization is sufficient, but with low-grade second and third sugars, molasses and similar products, the material should be polarized before and after inversion, the Clerget method being used.

The highly refined sugars are probably never adulterated. The only substitution which could be practised would be the addition of dextrose, and this is precluded on account of the hygroscopic nature of the adulterant. Powdered sugar is occasionally found which has been adulterated by the addition of starch. The fraud is easily detected by dissolving the sample in cold water and examining the sediment with the microscope.

The chief adulteration of such foods as table syrup, maple syrup, honey and molasses consists of the addition of varying amounts of glucose.

With reference to molasses, we may assume as preliminary indications of adulteration that light-colored molasses which polarizes higher than 60° is almost certain to contain glucose; that a dark-colored molasses should polarize below 50° , and that any molasses which gives a right-handed reading after inversion is unquestionably adulterated.

The addition of commercial glucose to a syrup or molasses introduces another difficulty in the analysis, in that it renders the value of both the polarimetric and gravimetric determination of the sucrose rather problematic. The adulterant contains usually from 28 to 45 per cent. dextrin, and it is evident that at least a portion of this constituent is converted into dextrose during the process of inversion, thereby affecting both the polarization and, when the gravimetric method is used, leading to an erroneous result in that this dextrose will be reckoned as sucrose.

The presence of glucose in a syrup or molasses can be easily detected by the polarization before and after inversion, the inverted solution being read both as near as possible at the temperature of the direct reading at 87° , at which temperature the rotary power of the invert-sugar formed from the sucrose equals 0. A pure syrup or molas-

ses will always give a left-hand reading after inversion, and at 87° the reading will be zero or very nearly so. When glucose is present, however, the reading after inversion will be strongly dextrorotatory at 87° , owing to the dextrose and the dextrans of high specific rotatory power which are present in the adulterant.

Another method for the detection of glucose depends on the removal of all sugars by fermentation with yeast whereby the final solution contains practically no optically active substances except the non-fermentable dextrorotatory constituents, which are always present in commercial glucose. Of all the various methods proposed from time to time this is probably the most generally used and the most reliable, although the result is naturally purely qualitative and does not enable the chemist to form any opinion as to the quantity of glucose present. This is, however, not essential, the proof of adulteration being sufficient to condemn the food. The method is described by Sieben as follows:

Twenty-five grams are dissolved in 200 cubic centimeters of water, sterilized and mixed with about 5 cubic centimeters of starch-free beer yeast. After fermentation at about 20° C. the liquid is clarified, diluted to 250 cubic centimeters and filtered, 200 cubic centimeters evaporated to 50 cubic centimeters and polarized when it should exhibit only a slight dextrorotation. Another portion is inverted with hydrochloric acid and the reducing sugar determined gravimetrically when only traces should be obtained.

Among the non-fermentable substances present in commercial glucose are found gallizin and amylin, and they are in general believed to be detrimental to health, although this point has so far not been decided definitely.

[*To be concluded.*]

The "Series-Vapor" and "Heat-Waste" Engines, as Supplementary to Single-Vapor Engines.

BY R. H. THURSTON,
Honorary Member of the Institute.

(Continued from p. 314.)

Case IV—Constant Temperature-Range with the Rankine cycle and a properly adjusted terminal pressure gives the quantities tabulated as below:

TABLE IV.

Vapors.	t_1	t_2	t_3	t_4	t_5	τ_1	τ_2	τ_4
Water.	342	194	104	293	248	803	655	754
Alcohol.	342	158	104	293	248	803	655	754
Ether.	342	122	104	293	248	803	655	754
Carbon di-sulphide.	342	140	104	293	248	803	655	754
Chloroform. . . .	342	140	104	293	248	803	655	754

Vapors.	τ_5	p_1	p_2	p_3	p_4	p_5	λ_1	λ_2
Water.	709	17,310	1,442	153	8,705	4,103	869'4	975'6
Alcohol.	709	33,712	1,507	373	17,989	9,003	286'2	397'8
Ether.	709	65,328	3,524	2,526	36,090	21,501	99'4	158'1
Carbon di-sulphide.	709	36,708	3,245	1,721	22,943	14,342	108'2	141'2
Chloroform.	709	29,845	2,092	1,020	18,433	10,936	92'6	130'0

Vapors.	λ_4	λ_5	K.	D_1	D_2	D_4	D_5	τ_2
Water.	908'5	940'7	1	317	029	164	081	9'37
Alcohol.	311'6	336'2	066	1'572	171	866	447	18'59
Ether.	116'3	130'1	067	4'911	903	2'798	1'717	18'53
Carbon di-sulphide.	120'1	130'0	257	2'832	623	1'827	1'180	8'25
Chloroform.	94'0	98'8	246	3'611	695	2'301	1'405	12'23

Vapors.	T_4	T_5	W	H	E	F	M
					<i>per cent.</i>		
Water	1'83	3'57	54,829	272,528	20'12	11'44	1
Alcohol	1'83	3'54	127,592	592,994	21'52	24'40	'853
Ether	1'85	3'11	202,506	910,954	22'23	48'02	'535
Carbon di-sulphide .	1'47	2'18	87,758	368,310	23'83	63'88	'550
Chloroform	1'58	2'60	94,793	410,058	23'12	75'42	'761

The quantities and the accompanying diagram, exhibiting the same facts graphically, are peculiarly interesting in this connection. In these comparisons, we find steam at a

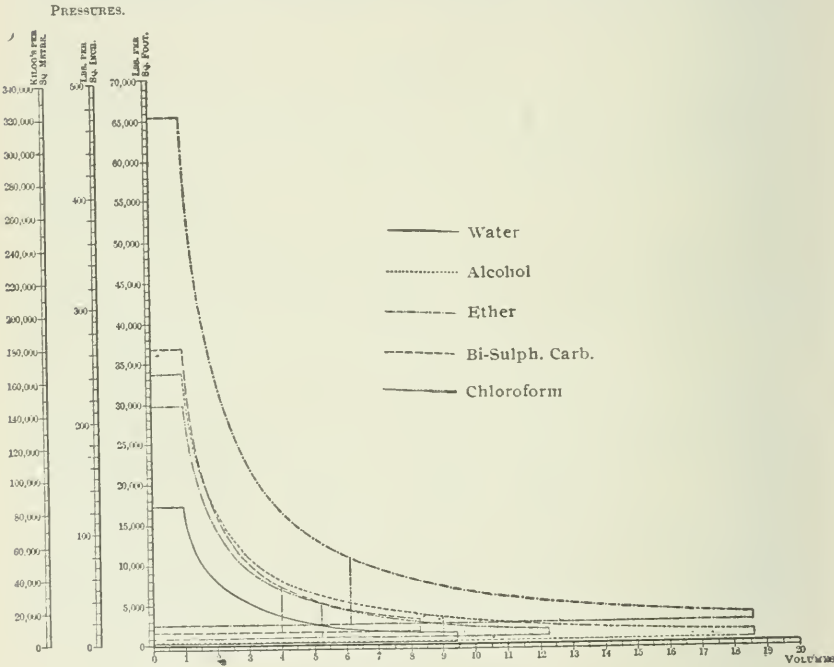


FIG. 3.—Rankine cycles. Temperature-range common.

disadvantage in efficiency, because of its restriction of pressure-range at its upper limit, the more volatile fluids having an advantage of several per cent.; while it is also at a disadvantage in respect to size of engine required for the same amount of power. It is now perhaps more easily

seen just where the advantages of a possible utilization of a more volatile fluid may be found, either as with the Campbell engine, in a simple construction, or as in the Du Trembley and other plans, as a series-vapor system.

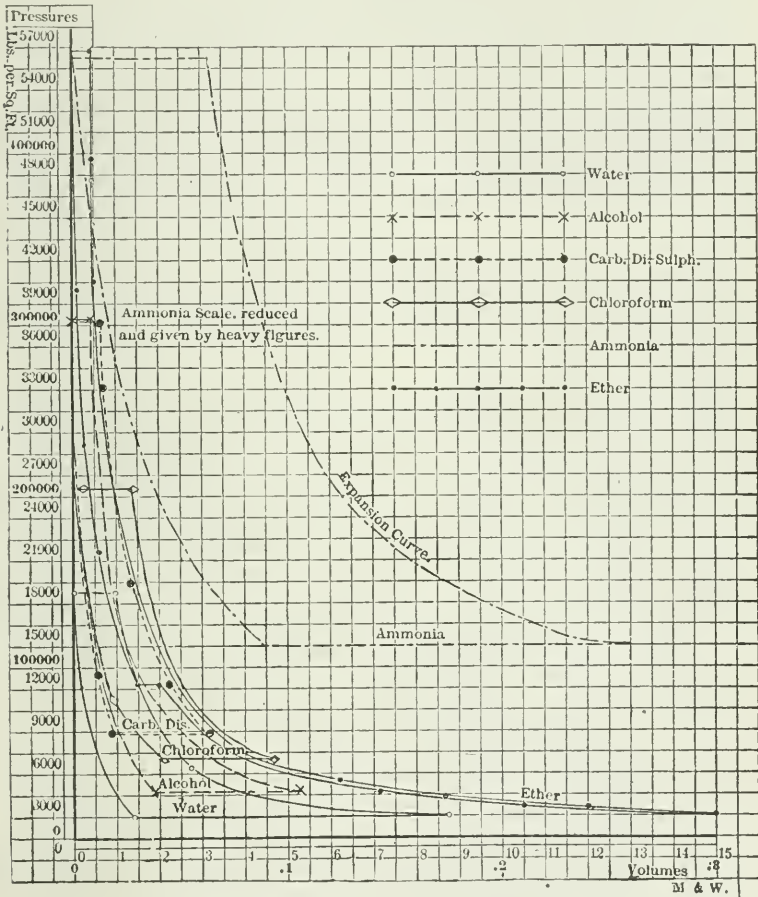


FIG. 4.—Carnot cycle. Common $T_1 - T_2$ and H .

Regarding the use of either vapor to the exclusion of steam, the investigators whose work is here summarized, reach the following conclusions:

(I) Steam, within the limiting pressure-range customary with the steam-engine of to-day, is the most desirable working fluid.

(2) The advantages of the non-aqueous vapors, proposed as substitutes for steam, may be gained with the latter by increase of initial pressure.

(3) The general deduction is, that "none of the non-aqueous vapors will successfully compete with steam."

The later and vastly more complete studies of the practically utilized volatile fluids, especially as supplementary or secondary fluids, may be presently found to somewhat modify these conclusions; but they must evidently stand until ample experience in the use of the rival fluids shall give positive proof of permanent gain by the use of the latter.

It should also be remarked that some correction of the figures may be found possible; but the general result may be taken as a safe guide relative to the ideal case here studied.

This study was continued by Professor DeVolson Wood and his pupils, with results differing somewhat, numerically, from those already quoted, but with precisely the same final conclusion: "water is by far the best medium of the substances considered for transformation heat into power.*"

The following are the symbols and tabulated results which are here brought together to make the comparison with other data and conclusions convenient and conclusive:

T_1 = initial temperature in degrees Fahrenheit.

T_2 = final temperature in degrees Fahrenheit.

τ_1 = absolute initial temperature.

τ_2 = final initial temperature.

p_1 = initial pressure in pounds per square foot.

p_2 = final pressure in pounds per square foot.

h_{e1}, h_{e2} = the corresponding latent heats of evaporation of 1 pound of the fluid in B.T.U.

H_{e1}, H_{e2} = latent heats of 1 pound in foot pounds.

L_1, L_2 = latent heats of 1 cubic foot in foot pounds.

w_1, w_2 = weights of 1 cubic foot of vapor.

v_1, v_2 = volumes that the fluid would occupy if it were all vapor.

* "Transactions A.S.M.E.," Vol. XII, 1890.

u_1, u_2 = initial and final actual volumes.

K = mean specific heat of the liquid between the temperatures τ_1 and τ_2 .

W_E = total work of expansion.

W_C = total work of compression.

H = the heat used in foot pounds.

E = efficiency.

J = dynamic unit of heat = 778 foot pounds.

Studies of these efficiencies, made under the direction of the writer, by Messrs. Flowers and Walton, in which the formulas of Rankine and the methods of the writer * were employed, give the following:

TABLE V.—BINARY ENGINES.

CYCLES CORRESPONDING TO NON-CONDENSING STEAM-ENGINE.

P_1 (per square inch)	100	300	500
T_1 (F. abs.)	788.6	878.4	928.4
T_2	587.0	587.0	587.0
$T_1 - T_2$	201.6	291.4	341.4
Carnot efficiency	25.54	33.10	36.8
Rankine efficiency †	12.53	20.80	23.60
Recorded by ether	87.47	79.20	76.40
Ether cycle efficiency	11.50	11.50	11.50
Combined efficiency	22.58	29.91	32.39
Steam per horse-power hour	10.18	6.96	6.23
B.T.U. ₁	11,270	8,500	7,800

CYCLES CORRESPONDING TO CONDENSING STEAM-ENGINE.

P_1	100	300	500
T_1	788.6	878.4	928.4
T_2	531.0	531.0	531.0
$T_1 - T_2$	257.6	347.4	397.4
Carnot efficiency	32.7	39.58	42.8
Rankine efficiency †	12.53	20.80	23.60
Recorded by ether	87.47	79.20	76.40
Ether-cycle efficiency	17.42	17.42	17.42
Combined efficiency	27.76	34.60	36.91
Pounds steam	8.28	6.02	5.46
B.T.U.	9,167	7,355	6,895

The accompanying diagram exhibits the progress-curve for these cases, the efficiencies rising rapidly at the lower

* "Manual of the Steam-Engine;" Vol. I, Chap. IV.

† Steam, dry and saturated, as in Rankine's "jacketed engine."

ranges of pressure and tending to become asymptotic with the base-line in the upper ranges—a familiar fact but often overlooked. The comparatively small gains in the more radical practice evidently point to a limit at which, in all cases, we approach a balance between gains and losses, direct and incidental. The practical limit of the commercial case is often far within that of the ideal, purely thermodynamic case. In the present instance, the practical is more closely approximated to the ideal through the facts that the ether normally superheats with expansion, and that

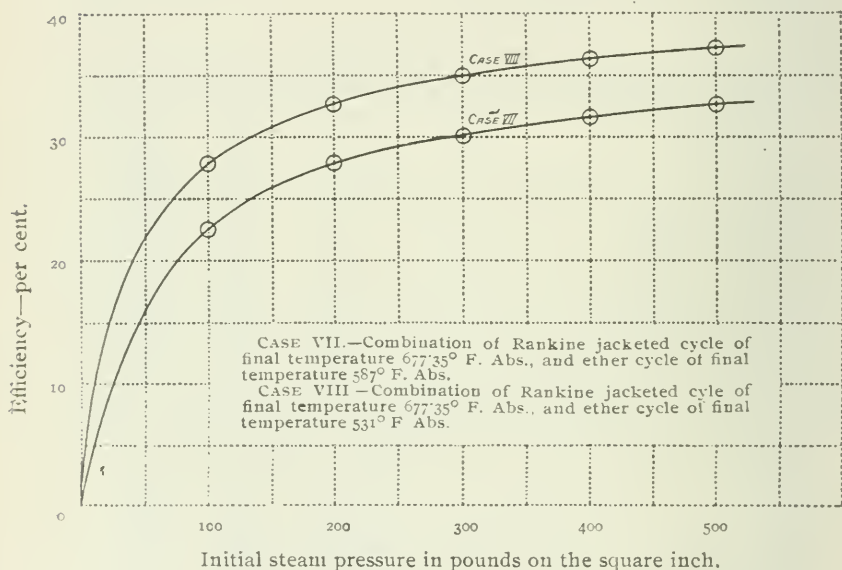


FIG. 5.—Combined engine efficiencies.

its latent heat of vaporization is low, giving high pressures at the minimum of the temperature-range. In the above case, also, the back-pressure remains high and the opportunity for still higher economy is seen. But a comparison of the figures given for efficiency by these investigations indicates a comparatively close approximation to the ideal for the combined system.

The Finance of the Case is influenced by several distinctly different considerations—in part internal, in part external—

partly relating to costs and prices of constructions and heat-stores ; partly to values and costs of rejected heat and profits of use of the heat-economizing system. It is evident that in some cases it may be found that the saving effected by the use of the system proposed may prove to be small, or actually zero, or even a negative quantity, depending upon the magnitude of the waste, the cost of its reduction and the value of alternative methods.

Primarily, the question is one of choice between one and another method of economy and the resultant value of the rejected heat. It may be the fact that the heat rejected has as great value for other purposes, as for heating, for example, as has the prime steam. In such case, it is not a matter of economy to save it at all, and it may be that a non-condensing engine, rejecting sufficient heat to satisfactorily meet the demand for heating, or in a woolen mill, for the dye-houses, will prove a more economical machine than the most perfect of condensing engines wasting heat from its hot-well. Where the rejected heat may be in any way so utilized as to make its value equal to, or nearly equal to, that of steam direct from the boiler, the net result is the equivalent of that obtainable with a heat-engine of efficiency *unity*. Condensers and "heat-waste" accessories are, in such cases, costly and wasteful adjuncts.

In a large proportion of our electric light and power distributions, the steamplant wastes a very large part, often 75 to 85 per cent. of the energy of the fuel, or even more, in some instances; and this waste may frequently be substantially all saved by diverting the rejected heat into a heating system for the adjacent properties. In numerous cases, if not in most, a choice of methods of saving rejected heat is offered the engineer, and it becomes his duty to select that which, all things considered, will give the most satisfactory return when viewed from the standpoint of the investor in after years. This may mean complete utilization, or complete waste, of the rejected heat; it may compel the use of a non-condensing and inefficient engine for a good modern high-pressure plant; of the condensing-engine, or of the most refined construction of steam-engine, reinforced,

as at Berlin, by a "heat-waste" accessory. The right decision is, in fact, determined by financial considerations and is absolutely definite for each case. The engineer's duty is that of identifying that precise solution of the problem. A steam-engine introduced into the line connecting a battery of boilers employed for heat, or for use in dyeing and bleaching, with its work will abstract simply the mechanical equivalent of its power from the passing current of steam, and the balance will be none the worse for the loss; while the engine will produce its power with unity efficiency, giving to work 778 foot-pounds per B. T. U. thus abstracted. If, under usual conditions, the horse-power costs \$30 a year, where the efficiency of the heat-engine is 20 per cent., in this case the crude non-condensing machine will provide it for \$6. With lesser values of heat rejected and higher costs of its production, the comparison changes in the direction of justification of expense incurred in its utilization of otherwise lost energy. With high cost of production and high values of power produced, large costs may be profitably incurred in the provision of a system by which to economize the wastes, even of a good condensing-engine.

The absolutely ideal method of employment of thermodynamic machines, subject, as are all known forms, to an unavoidable waste of a large amount, is to use them where there exists a demand for a constant supply of steam or heat, for other purposes, of more than equal quantity with their wastes, and securing unity-efficiency by placing them, as above, in the path of that heat-supply. This system will often be found entirely practicable, under existing conditions, and may very often be made practicable by proper combinations of industries requiring heat and steam in considerable quantity.

In every field of engineering, the fundamental principle which limits progress in promoting efficiency is: Improvement may be carried to that point at which further advance will cost more than the gain, and at which a lesser efficiency would mean a sacrifice of economy more than equal to the saving in cost. This particular improvement will find its limitation in application under any given conditions at this

financial critical point, however successful, practically, it may prove to be.

The Limit of Expansion.--As in all heat-engines, the terminal pressure on the expansion-line is fixed in the series-vapor engine for each individual case by the principle which asserts that the limit is reached when the income of the plant, or its net output per unit of cost, would be reduced by either increasing or diminishing the ratio of expansion. The limit is set in practice more commonly by that at which the consumption of heat, steam and fuel per horse-power-hour would be increased by such variation from the limit; which latter is not a correct solution of the problem.

The terminal pressure is found by experience, as a general rule, to be not far from one-third of an atmosphere in excess of back-pressure at about 6 or 8 pounds per square inch absolute, in the condensing engine, and 20 pounds or more for the non-condensing engine, when maximum economy of fuel is sought, and probably considerably higher in many cases, on a correct commercial basis; but it is very variable with varying conditions of the market for fuel, for construction and for capital and labor.

With the series-vapor engines, the profitable limit is usually elevated by their higher cost to a figure somewhat above that for steam. Its exact magnitude must be a subject of investigation in the individual case. The advantage gained by the use of these vapors when accessory to steam, as in the binary-vapor engine, is that of securing the desired limiting pressure at a lower point on the temperature-scale. This means the extension of the heat-transformation through a wider range of temperature and a corresponding gain in thermodynamic efficiency. This effect is precisely the same, so far as thermodynamic action is concerned, as the extension of the temperature-range for the single vapor in the steam-engine. It is thus entirely correct to assume that the steam-engine of equivalent value is that in which this range is to this extent widened, and to compute the efficiency of such a steam-engine as being that of the proposed equivalent series-vapor engine and to accept comparisons on this basis.

Experience with the steam-engine shows that, with that machine, at least, and presumably with every machine in the class, there is a certain terminal pressure in the working cylinder, below which it is undesirable, on economical grounds, to expand the working fluid; since any gain of work is more than compensated by added wastes by friction and other losses. In steam-engines of the larger sizes and better class, this limit is found at a terminal pressure of from 5 to 8 pounds above the back-pressure, in marine practice, and, especially when the accessory wastes of transmission and of finance are taken into account, it is likely that the figure should be at least 50 per cent. higher; while in small and cheaply constructed machines, and where fuel is cheap and machine-work costly, still higher terminal pressures are representative of best practice. Presumably the same principle holds, and in about the same measure, in the binary vapor-engine. The "waste-heat engine" in its ideal form, may be defined, therefore, as one in which, by suitable choice and use of working fluids, the net effective pressure of the expanding fluid, despite falling temperatures and transformation of heat into work, is maintained at magnitudes considerably in excess of the limiting terminal pressure for the engine. That secondary fluid in this respect is best, other things equal, in which the final pressure at the lower limit of available temperature in the working cylinder is highest, that is to say, the most volatile.

Another method of stating the principle of the multiple-vapor-engine is found in the assertion that the main purpose of the complication is that of securing increased terminal pressures with a view to elevating the mechanical efficiency of the engine. The use of vapor, or of a series of vapors, therefore, in which, as temperature falls, the correspondent pressure shall relatively rise, is the obvious means of accomplishing this purpose.

Available fluids include ammonia, chloroform, sulphur dioxide, ether, carbon di-sulphide, and, in fact, any fluid having a low boiling-point at ordinary pressures. A whole series of petroleum products may be included as available in a "series-engine," as the writer has called it, where, as

has sometimes been proposed, notably by Wellington, a multiple-cylinder engine is provided with a "multiple-series" of such substances, each adapted by its special relations of temperature and pressure to its appropriate cylinder and the boiler for each of which serves as the condenser for that next higher in the series.

Each of the known available secondary or series-fluids has its own objection, however, and often more than one. All are costly—some, dangerous—from their physical qualities, as illustrated by the stifling properties of ammonia, the peculiar effects of chloroform, the inflammable nature of the petroleums. These objectionable properties may prove fatal to general employment in this class of heat-engine, even though otherwise entirely satisfactory. Probably their costs are not likely to prove very objectionable, as once introduced into the apparatus, they circulate constantly, without any other loss than that by leakage, and this may prove not to be an insurmountable difficulty of construction, notwithstanding the fact that the surface condenser is commonly now composed of tubes fitted into tube-sheets, thus compelling the user to deal with numerous joints. The joints may be either suppressed or made safe against liability to sensible leakage. The danger of accidents, permitting deleterious substances to find their way out into the surrounding atmosphere, may prove less easy of avoidance. This risk, which has led to the use of the air-refrigerating machines, in place of ammonia-machines, on shipboard, is one to be seriously considered in the choice of secondary fluids. The magnitude of this and of other insurance risks, and their financial evaluation, become elements of the problem of "maximum commercial efficiency," the ultimate problem of the engineer, here as everywhere else.*

A multiple-fluid engine, including a gas-engine—from which, as a rule, one-half of the heat of combustion is discharged by way of the jacket, the waste heat being ejected

* Commercial Efficiencies: "Manual of the Steam-Engine," R. H. Thurston.

at a very high temperature both into the jacket and through the exhaust—presents the very best of opportunities for utilization of the series principle. Such a series might be illustrated in a supposable case in which the heat rejected from the gaseous working fluid should produce steam for use in an accessory steam-engine, this in turn to reject its waste heat into an ammonia or a petroleum engine and this, again, into other engines, in sequence, employing lighter petroleums, and, possibly, terminating the series with an ether or ammonia engine. Such series-engines have often been proposed, but none have proved commercially persistent.

In the earlier days of the steam-engine there was comparatively little opportunity to introduce the vapor-series engine and little inducement to seek utilization of waste heat. The wastes were large in quantity and due to crudeness of design and to conditions generally capable of large improvement without change in the type of engine. The time for the series-engine had not arrived. Possibly this may prove to be the fact to-day; but conditions have greatly changed, and it may prove practicable as well as expedient to endeavor to utilize the still large amount of waste heat rejected from the engine between the temperatures of the condensing water and that of the terminal pressure on the expansion line, notwithstanding the fact that this may involve the adoption of more elaborate constructions and of more refined systems of heat-transformation.

An important practical condition, affecting seriously the availability of the series-fluid engine, is the difficulty of avoiding in those elements of the series which have a terminal pressure lower than atmospheric, the leakage of air into the system and the resultant vitiation of the vacuum in the condenser. Thus, in the steam-engine, the minimum temperature of hot-well and condenser is usually not far from 110° F., and the vacuum at the sea-level is usually not higher than 25 or 26 inches, although 27 is sometimes attained and still more rarely maintained. The condenser, when absolutely tight and free from air, would exhibit a

vacuum of about 28 at the lower temperature, and the higher temperature, 130° or 140° , corresponds to the actual vacuum observed—about 24 inches—without leakage. It is not to be expected that any vacuum obtainable from the accessory fluids will be less affected by leakage. On the other hand, it is to be observed that the suppression of leakage may result in the increase of the mean effective pressure of the steam-engine by from 2 to 5 per cent. and with the multiple-fluid engine in some further exaltation of the pressures accompanying the lower temperatures of working fluid.

The suppression of leakage can now be effected vastly more completely than in Rankine's time, as finer workmanship and more perfect systems of packing of piston-rod and valve-stems now enable the builder to put into the hands of the user a practically tight machine. This improvement in apparatus affords opportunity to improve both the older and the newer form of heat-engine, and the latter even more than the former. Similarly improved methods of construction permit the reduction of the costs of the more complicated machine, thus aiding in making necessary complications more unobjectionable on that score. The commercial failure of an improved construction at the middle of the century is thus not a proof of unavailability at its end, and is no bar to repetition of the experiment.

The Use of Volatile Fluids, as primary or secondary working substances for heat-engines, where comparatively low temperatures were to be dealt with, was suggested a century ago by Sir Humphrey Davy, who proposed thus to utilize the wasted heat of the water of condensation discharged from the steam-engine, making that element of the machine the boiler of a secondary engine—of a "waste-heat engine," as it is coming to be called.

The idea was taken up by Mr. Ainger in his lectures, about 1830, before the Royal Society, and his suggestion was that *ether* should be employed as the secondary fluid in carrying out the plan of Davy. Since that time numerous scientific men and inventors have adopted the idea, and a considerable number of binary-vapor engines have been

constructed, in which ether, chloroform, ammonia and other volatile fluids have been employed, more or less skilfully, in the promotion of the improvement of the heat-engine in this direction.

The experiment of the French inventor, Du Trembley, was the first on a commercial scale and with apparatus constructed by expert builders. This attempt to utilize the principle here discussed was made in a number of steamships on an established ocean route, and on a scale which was entirely satisfactory, so far as the comparison of the older and the newer form of heat-engine was concerned. Its outcome was unfavorable, not from any defect in the plans of the inventor, but solely from the fact that the secondary fluid chosen was readily combustible and, at that time, at least, difficult if not impossible to confine permanently, completely and safely within the vessels in which it was expected to be utilized. To-day, the fluid would be no less dangerous if free; but the probability of it finding its way outside the engine by leakage would be greatly lessened by the better workmanship of our time. Such a fluid is, however, particularly objectionable on shipboard.

The French Government appointed a commission to investigate and to report upon the work of Du Trembley, and they studied the action of his binary-vapor machine as operating at the time in the steamer "Du Trembley;" the designs being those of Du Trembley, the steamship line that of Messrs. Arnaud & Touache, of Marseilles; the installation and operation being under the supervision of Mr. Jamieson, the superintending engineer.

The report of the commission stated that the engines of the ship were rated at 70 horse-power, arranged to be used together or separately. In the words of the report: "Sulphuric ether, requiring but a feeble heat to volatilize it, it seemed to him" (the inventor) "fitted to realize his ideas. He made the experiment and the result fulfilled his hopes. As soon as the vapor of water was in contact with the ether, it fell instantly to the liquid state and the ether evaporated. On the one hand, a new expansive force was created; on the other, a vacuum, which is also a force, was formed." Du

Trembley fitted his steam-engine with a surface-condenser, which served the double purpose of condenser for the steam and boiler for the liquid ether. The vapor thus produced was transferred into a secondary engine, constructed precisely alike the steam-engine in plan, and then was utilized by thermodynamic transformation to such extent as to add very considerably to the total power of the motive apparatus. The vapor rejected from the secondary cylinder was condensed in a surface condenser and returned to the vaporizer, whence it obtained its store of available energy at the commencement of its cycle. This constituted the "system of combined vapors of M. du Trembley."

The consumption of fuel with the engines using steam alone was reported by the commission as 4.31 to 5.51 kilos per horse-power hour, 9.5 to 9.9 pounds; and with the combined system, 1.11 to 1.16 kilos, 2.44 to 2.56 pounds.

The commission states that the cost of the ether is unimportant as affecting the ultimate economy of the system, and they assert that "the system of M. du Trembley presents a notable economy," and that, on the whole, it is a great advance. They consider the danger of ether very slight, being, as they say, "neither greater nor less than those of employing carburetted hydrogen-gas for illumination."

Several later ships were fitted with engines on this system. The "Jacquard" was found to suffer seriously—to be greatly endangered—by the escape of the combustible vapors of ether; and the engineers employed miners' safety-lamps in the engine-room. The secondary fluid was finally abandoned. The "Arago," fitted for a secondary system, was not so operated. The steamer, "La France," was burned at Bahia through the ignition of the ether, and the danger of approaching the tanks containing the supplies of that fluid was such as to prevent the efficient action of the fire department. The ship was destroyed. This misfortune closed that period of experiment with ether as a secondary fluid in binary engines.*

Sulphuric ether, employed by DuTrembley as the secon-

* See "Bourne's Treatise on the Steam-Engine," 1866, p. 393.

dary vapor in the binary engine, has this peculiar thermodynamic advantage over steam: that it superheats during adiabatic expansion instead of condensing. This, in the engine-cylinder, in the working engine, is a distinct advantage, as it tends to hold the fluid in the superheated, the gaseous, condition throughout the period of expansion and thus to restrict "cylinder condensation," initial condensation, of the working charge and that form of waste which is the most costly tax upon the steam-engine. Restricting heat-exchanges between the working fluid and the metal of the cylinder by this automatic action of superheating should therefore give such substances definite superiority over the fluids which, like steam, tend to condense with performance of work in the engine and thus to promote waste. It is doubtful, however, whether it will prove practicable to introduce such substances as rivals of steam, when, as in the case of naphtha and of ether, the fluid is readily combustible and explosive.

The experimental examination of the Du Trembley binary engines gave results which are, in essentials, the following:*

Initial pressures	Steam, 43·2 lbs.;	Ether, 31·2.
Back-pressures	" 7·6 "	" 5·3.
M.E P.	" 11·6 "	" 7·1.

The steam supplied, thus, 62 per cent. of the total power; the ether, 38 per cent.; but the comparison between the steam-engine employed without the secondary and the latter as then utilizable by employing simply the water-heat of the primary, under the best conditions for the steam-engine, would have been more nearly steam 75 and ether 25, which latter figure is that giving the real accession of power due the secondary engine.

The consumption of fuel, as reported by Gouin, was between 2·4 and 2·8 pounds of good coal per horse-power hour, a figure which was soon improved upon by steam-engine builders without employing a secondary fluid.

Du Trembley built for the French steamer, "Brésil,"

* Gouin's Report.

engines of considerable size and power, and again made a test on a large scale of the Steam-and-Ether Engine, about 1850. It was reported by M. Gouin that the consumption of fuel was as low as 2.44 pounds per horse-power hour, a decided improvement upon the steam-engine of the time. The compound marine steam-engine later introduced, and which is a fair standard of comparison, still further improved upon these figures. It was from these results that Rankin was led to a consideration of the problem of the series-engine and to declare that "the binary-vapor engine is not more economical than steam-engines designed with due regard to economy of fuel; but, by the addition of an ether-engine, a wasteful steam-engine may be converted into an economical binary-vapor engine."

A generation later, Messrs. Haswell, Goring and Torrance tested a binary engine in which carbon disulphide was the secondary fluid and obtained, as reported, the horse-power hour of 1.4 pounds of good coal. The trial was, however, too short, and the result too extraordinary for a small engine of less than 90 horse-power, to permit the acceptance of the reported figure without further investigation. In this engine, the rejected heat from steam of 15.3 pounds pressure was reported to produce a pressure in the secondary fluid of 76 pounds, by gage, substantially equal to that of the steam-boiler supplying the steam to the primary element of the combination. The trial was but five hours long and involved cleaning the fire. It must probably be admitted that the machine was very economical of fuel and steam.

Mr. Barrus, in 1887, reported the results of a trial of a new form of heat-engine in which the single fluid employed was ammonia, and the results were checked by operating the same engine with steam alternately with the ammonia. The outcome of the trial would seem to indicate the correctness of the surmise of the writer that wastes of heat by extra thermodynamic processes may be less with other fluids so used than with steam.

The data and results obtained by Mr. Barrus, by three tests of a Campbell ammonia-engine and boiler, as reported

to the Campbell Engine Company, April, 1887, were as follows:*

TABLE VI.—AMMONIA ENGINE.

DIMENSIONS OF BOILER AND ENGINE.

Boiler.—One horizontal-return tubular, set in brickwork.

Diameter of shell	42 in.
Length of shell	10 ft.
Inside diameter of tubes	1'75 in.
Area of water-heating surface	369'3 sq. ft.
Area of steam-heating surface	318'8 "
Area of grate-surface	9'17 "
Collective area for draught through 67 tubes	1'12 "
Ratio of water-heating surface to grate-surface	40'3 to 1
Ratio of steam-heating surface to grate-surface	33'6 to 1
Height of smoke-stack above grate	30 ft.

Engine.—Porter-Allen automatic cut-off, single cylinder.

Diameter of cylinder	11'5 in.
Stroke of piston	20 "

DATA AND RESULTS OF TESTS.

Date	1887, March 8,	March 9,	April 16.
Duration of test hours	8	10	7'45
Percentage of ashes, etc. per cent.		9'9	8'2
Coal per hour per sq. ft. of grate . . . pounds	19'09	15'27	16'07
Boiler-pressure above atmosphere . . .	100	95'5	86'6
Temp. of feed-liquid entering boiler . deg. F.		167'6	167
Temp. of gases entering stack "		39C	394
Vacuum in feed-well inches		11'5	11
Revolutions of engine per minute . . . revolu.	205'2	204'5	201'5
Indicated horse-power developed by engine H. P.	61'80	57'53	54
Proportion of stroke completed at cut-off		189	211
Proportion of stroke completed at release		773	791
Proportion of return stroke uncompleted at compression		307	342
Coal consumed per indicated horse-power per hour pounds	2'832	2'433	2'729

The report upon the performance of the carbon-disulphide engine above referred to gives in detail the following facts and data:†

* "Manual of the Steam-Engine," Vol. I, p. 702.

† "Manual of the Steam Engine," Vol. I, p. 701.

The engine was of the Corliss type, jacketed, 16 inches in diameter of piston and of 4-feet stroke. The power was absorbed during the trials by a prony brake. It could thus be operated by either steam or other fluids. The boiler was the usual form of tubular, with plain cylindrical shell. Its heating surface measured 1,028 square feet; its grate, 21'6. The fuel was a bad quality of anthracite. Natural draught was employed.

The boiler produced steam which, in the operation of the system, circulated from the boiler through a vaporizer constructed like a surface-condenser, and thence flowed back to the boiler as hot feed-water. The vapor of CS_2 thus generated passed on to the engine as required, and on through its cycle, including a surface-condenser, where it was condensed and whence the liquid was pumped back into the generator or vaporizer. Both steam and CS_2 thus continuously, during the operation of the system, flowed in closed cycles and no loss of either fluid occurred if all worked properly.

The supply pipe and the cylinder were both jacketed with steam at boiler pressure. No leakage was discovered, either of the CS_2 or of the H_2O .

The period of reported trial was seven hours.

During the earlier steam-tests, the engine, without the secondary element, was reported to have used 4 pounds of anthracite coal per horse-power hour.

The following are tabulated data of the trial with CS_2 :

TABLE VII.— CS_2 ENGINES.

ELEMENTS OF OPERATION AND RESULTS.

Date of trial	January 16, 1894.
Barometer	29'17
Temperature of external air	51'0 F.
Pressure of steam at boiler	78'73 lbs.
" " " generator	75'16 "
" " " shell	22'46 "
" " " in steam-jackets	70' "
" " CS_2 at generator	95'8 "
" " " steam-chest	93'96 "
Vacuum in condenser	10'47 "
Feed-water used	13352 "
" " " per hour	1907'5 "

agement." The experts reporting upon the trials of the engine conclude that one-third less heat, steam and fuel was required by the engine when using ammonia than as a steam-engine—condensation being adopted in both cases.

No difficulty appears to have arisen in the operation of the "plant," and leakage did not occur to any appreciable extent; only a slight odor of ammonia being observable about the stuffing-boxes. The apparatus was in operation for several months in New York City. Other conclusions of the experts were: The apparatus may be easily arranged by utilization of any condensing steam plant, surface condensation being required, however, and the replacement of all brass parts in contact with the working fluid by iron or steel; joints are easily made with rubber gaskets; boiler-risks are reduced rather than increased by the substitution of aqua ammonia for water therein. These results were obtained by three independent investigators.

It was reported that the machine, employed as a steam-engine, demanded considerably more fuel than when used as an ammonia-engine, when the figure was about 2.4 as a minimum when delivering about 60 horse-power, the duration of the test being ten hours. Another inventor, Mr. Ellis, supplemented the steam-engine by an ammonia-engine and obtained very similar figures. Other attempts in this direction have given good results.

A multiple-vapor series-engine was proposed by Wellington, who, having spent a large amount of time and money in preliminary work, died without having reduced his invention to practice and without having determined its value or even its promise. He proposed to employ a vapor-series, like, for example, the petroleum of varying densities, selected to suit the purpose, worked in a corresponding series of cylinders, *en cascade*, as it is termed by the French. His plan has never been fully developed or tested.*

"Cylinder condensation" obviously affects the multiple-cylinder engine—other things equal—less than the simple,

* "Manual of the Steam-Engine," p. 700.

whether the machine be also a multiple-vapor or multiple-fluid engine or no; and if the secondary fluid is less liable to this method of waste than its primary—the steam, the gas or the air-engine—the two gains conspire to reduce the wastes of the heat-engine taken as a whole. There is some evidence that those secondary fluids which have usually been adopted, in such multiple-fluid engines as have been hitherto experimented with, are less liable to this form of waste, exhibiting sometimes much less tendency to heat-transfer between working substance and cylinder wall than steam. But it is probable that much more work must be performed in this field of research before we shall secure satisfactorily definite knowledge on this subject.

Light petroleum has been employed as a working fluid in heat-engines; and while the experiment has been on too small a scale to permit a definite judgment regarding the value of the fluid for its purpose and while the properties of the substance which affect its thermodynamic value have not been yet ascertained, there is some evidence that it may prove, on the whole, a more efficient working fluid than steam, and to possess other advantages, consequent upon its physical nature, which give it standing in this field. But it is exceedingly inflammable, liable to remarkably violent and dangerous explosions, and thus particularly objectionable where, as on shipboard, it must be stored in considerable quantities under circumstances favorable to destructive results in case of becoming accidentally fired. As a fuel, it is rich in thermal energy, compact, readily stored and very easily and cheaply manipulated; as a working substance in the engine, it probably will be found to possess the special advantage of limited “cylinder condensation” and of performing the part of a lubricant on the piston and rod.

The light petroleums have no fixed boiling-points, as they are composed of a variety of definite compounds having a similar variety of physical properties and boiling at different pressures and temperatures. In vaporization, they boil in the order of their volatility, and the pressures which correspond to their boiling points, usually high in

comparison with steam, follow a similar order. Thermodynamically, they have, in many cases, excellent qualities for the series heat-engine.

Where they have been used, as in the experimental work of Mr. Yarrow, it has been found that a comparatively small area of boiler-heating surface is required for a stated efficiency of vaporization and the whole apparatus may be made exceedingly compact.

Mr. A. F. Yarrow's work with petroleum engines was sufficiently extensive and fruitful to at least give those fluids peculiar interest, considered as working substances in engines.* His investigation had its origin in the observation of experiments previously carried on in the United States with petroleum engines in small launches or yachts. The first comparison of work obtained with steam and with petroleum spirit, used alternately in the same engines, resulted in the conclusion that, with equal expenditure of heat, the petroleum engine supplied about twice as much power as the same machine operated by steam. The following are the figures reported:

Quantities.	Steam.	Spirit.
Cubic feet gas-fuel per hour	82.20	83.48
Gage-pressure	37.99	55.80
Revolutions per minute	312.60	552.20
Brake-tension	1,154	1,222
Foot pounds per minute	2,524	4,722
Indicated work	5,199	11,975

The figures are thus nearly two to one in favor of the spirit. Also, the measurement of the indicator diagrams gave similar results to those obtained by brake; the work of the steam-engine being found to be 5,199 foot-pounds per minute; that of the petroleum engine being 11,975. The "spirit" used had a density of 0.680, water being taken as unity. Gasolene, equally available, has a density of 0.650, benzine of 0.725 and refined petroleum approximating 0.800. The light petroleums all have one common and serious objection—their inflammability—which, combined

* "Proceedings Brit. Soc. Arts," May 22, 1889. *The Engineer*, London May 31, 1889, p. 470.

with their volatility and vicious explosiveness, makes them peculiarly dangerous wherever inclosed in such manner that their vapors, when leakage occurs, cannot be freely swept away by currents of air.

Mr. Yarrow built many small launches with petroleum engines and with great success, from the builders' and the engineers' points of view. They could, when 36 feet in length, attain a speed of 8 miles an hour and carry fuel for 200 miles. They could be started in five minutes from the instant of lighting the fires. The machinery was very light and the fuel, also petroleum, was the most concentrated possible form of stored heat-energy. Experience showed it to be possible to make the waste-heat exceedingly small in amount, the hand being, as the builder reported, held over the chimney when in action without inconvenience, in the case of the so-called "Zephyr" launches thus constructed.

Later experiments with launch engines were reported by the same constructors, in which a similar comparison was made by using the engines alternately as steam and as petroleum engines.* The same general results were obtained and the petroleum engine produced double the amount of power given out to the brake by the steam-engine with equal quantities of heat and fuel. The brake showed a ratio in favor of petroleum of 1.878; the indicator, also, exhibited a ratio of 2.303. The operation of the boats supplied with such engines confirmed the deductions from the brake trials.

[To be continued.]

LIQUID FUEL FOR STEAMERS.

According to recent English exchanges the Red Star liner "Kensington" has been ordered to the Tyne, where she will be fitted with patent oil-burning furnaces by the Wallsend Slipway and Engineering Company, Limited. Whereas the previous vessels converted into oil-burners by this company have been tank steamers, the "Kensington" is a large Atlantic trader, and will be the first vessel of her type that the Wallsend firm has adapted to oil-burning.

* *London Engineering*, June 22, 1888, p. 609.

A New Device for Stereoscopic Photomicrography.

BY FREDERIC E. IVES.

I have recently made a one-plate-one-exposure stereoscopic photomicrographic camera which is interchangeable with the single camera on the adjustable base described in the *Journal of the Franklin Institute* for May, p. 375. It consists of a light telescopic box camera for plates $3\frac{1}{2} \times 6$ inches, which is provided at the front with a small prism box containing three equilateral prisms, so disposed as to divide the light at the eyepoint above the eyepiece of the microscope, and project the divided rays upward to form the two stereoscopic images. *Fig. 1* shows the parts drawn to scale. *A* is the camera, *B B B'* are the prisms, *C* is the microscope tube with objective and low-power eyepiece, *D* is the object slide, and the dotted lines show the path of the axial rays from the back of the objective.

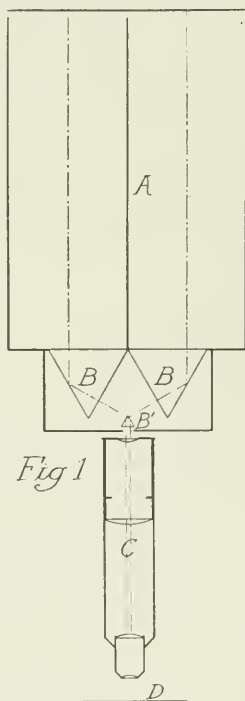
It is the usual practice to divide the light at the back of the objective, but inasmuch as the spot of light at the eyepoint, above the eyepiece, is an image of the back of the objective, it answers the same purpose, when working with an eyepiece, to divide the light at this point; and in the present device this is accomplished by the small equilateral prism. If this prism is perfectly accurate, the result is two images as perfectly stereoscopic and as perfectly defined and evenly illuminated as the images projected one at a time in the usual way; in fact, the images may be more evenly illuminated than is possible in the usual way when the objectives have long mounts.

By adding a lens of the focal length of the camera, for which there is room by using it as a cap for the eyepiece, the camera can be used without even refocussing, in the manner described in my communication already referred to.

The prism box has a lateral fine adjustment by screw on the camera front, in order to readily set it so that the apex of the small prism exactly bisects the circle of light at the

eyepoint. This adjustment can be made by looking through the prisms from the back of the camera.

I think it is a mistake to divide the light anywhere back of the objective when working with high powers on transparent objects, because some of the diffraction pencils, which define very minute details, emerge from the half of the objective opposite to that which belongs to the respective dioptric projection. It is probably for this reason that the Wenham



binocular cannot be made to perform satisfactorily with high powers. This stereoscopic camera, for precisely the same reason, should only be used for subjects which may be satisfactorily shown in the binocular microscope. With a 2-inch huyghenian eyepiece, amplifications from $\times 10$ (3-inch objective and short tube and camera) to $\times 120$ ($\frac{1}{2}$ -inch objective and long tube and camera) can be made satisfactorily by employing color-sensitive plates and a yellow screen.

With Zeiss' 16-millimeter apochromatic objective and the "finder" (2) compensation eyepiece, ordinary plates can be used without the color screen.

The negatives produced in this camera are ready for printing from, no transposition of images being necessary, and for this reason only I prefer it to two otherwise equally simple and efficient combinations with which I have worked.

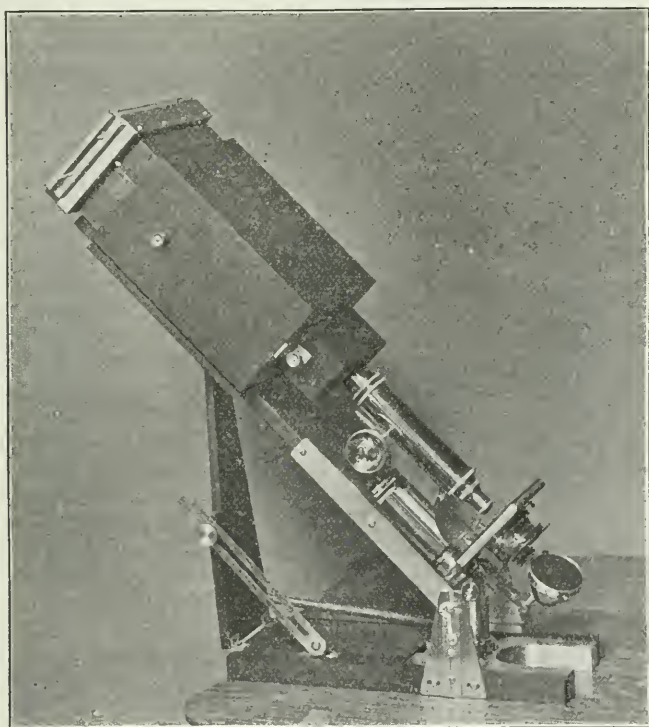


FIG. 2.

Fig. 2 shows the stereoscopic camera used on my adjustable base, as recently improved. This combination can be adapted to the microscope at any inclination and brought into action in a few seconds; and, after exposing, it is removed as a rigid whole by a single rectilinear movement of one hand.

Correspondence.

THE METRIC SYSTEM.

TO THE SECRETARY:—I have been greatly interested in the various expressions of opinion relative to the introduction of the metric system, and have been hoping to see something from some one resident in our sister Republic of Mexico, where for some six or seven years the metric system has been compulsory. One of our most influential New York journals, an ardent advocate of the metric system, is fond of saying, by way of argument, "Look at Mexico." That no one has spoken from Mexico is, possibly, because those engineers who are here find so little friction that the matter hardly attracts notice.

I came to Mexico about five years ago, on a twenty-four hours' notice, to take charge of one of the largest smelting plants in the country, and had barely time to reach the works before the date when the man in charge was obliged to leave, and for that reason had no time to look forward with apprehension to the difficulties which I would probably encounter with the metric system. Of course, it occurred to me that all weights and assays of ores from which the furnace charges were to be figured were in the metric system. But in this there was little difference, for, except the assays of silver and gold, the factors were all in per cents. We spoke of tons, but we meant metric tons. Arithmetically all routine was certainly easier, but not greatly so, except in obtaining metric tons from kilos, as compared with obtaining American tons from pounds.

As the works had been planned some five or six years previously, it was not surprising that all the plans were made in feet and inches, and that in construction and repair work we continued to use the same measurements. And so for four years I gave little thought to the metric system. I was probably like many of us Philadelphians, of partly Quaker origin, who use with equal facility the "plain" and "plural" languages, as the case may be. If it was ore purchased and assayed it was the metric system; if it was construction or repairs, it was feet and inches.

About a year ago I was sent by the company to the State of Chihuahua to superintend some new metallurgical operations, and it is surprising to me at this time to see the Babel of standards. The survey of the land upon which the works are built, as well as all levels, are in the metric system. The plans for all buildings and machinery are in the American system. A building so many feet long and so many feet wide is on such and such a meter level. All lumber ordered from Texas or from the mills in the Sierra Madre is ordered so many inches by so many feet in customary United States sizes. Local dealers sell you so many meters of such or such inch pipe, and the bill so reads. All valves and fittings come in inches. Of merchant iron you buy so many kilos of the dimensions given in inches, and I have a list-card from one of the Mexican manufacturers of bar and sheet-iron giving the dimensions in $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$ and $\frac{1}{16}$ of an inch, that would suit the most conservative of your correspondents. Obliging salesmen in the stores can always give you the

price in "metros" or "varas." Your cordwood has to be converted from "cargas" and your hay or straw from "arrobas." So completely, however, has the metric system come into use in the purchase of ore that only in very remote regions does one still hear of the "marco." It must be observed, however, that in all bills which are to act in the nature of receipts for settlement, the controlling factor of either weight or length must be in the metric system.

I believe that the United States should do all possible to advance the metric system, but from my experience in this most autocratic of republics, I do not believe, that should they make a compulsory law, either the advantages or apprehended difficulties would so immediately become apparent.

Yours truly,

R. C. CANBY,

MONTEZUMA LEAD COMPANY,

SANTA BARBARA, CHIHUAHUA, MEXICO,

September 12, 1902.

Book Notices.

Sur les Principes de la Mécanique Rationnelle. Par C. de Freycinet, de l'Institut. Un volume in-8 de viii-170 pages. Paris: Gauthier-Villars, 1902. (Price, 4 frs.)

The author discusses in Chapter I the concepts of mechanics—space, time, the relation of space and time or velocity, the definition of motion, force, mass, quantity of action, work, mass-motion, energy, center of mass or of gravity. Chapter II treats of the general laws of motion—the law of equality between action and reaction, law of inertia, law of the independence of action of forces, law of the mechanical equivalence of heat, remarks on statistics. In Chapter III the dynamic problem is treated. W.

Die Elektrolyse des Wassers: Ihre Durchführung und Anwendung. Von Victor Engelhardt (Mit 90 Figuren und 15 Tabellen im Text). Halle a/S. Verlag von Wilhelm Knapp. 1902. (Preis M. 5.)

The above entitled work constitutes the first of a series of "Monographien über angewandte Elektrochemie," which are to appear from time to time from the press of this publishing house. The announcement of this undertaking, with which the names of a large number of experts actually engaged in the electrochemical industries, should be of special interest to American manufacturers, engineers and inventors in this rapidly developing branch of applied science.

The present treatise on the electrolysis of water is made the first of the series, and very properly, since the phenomenon of the electric dissociation of water, both from the historical and scientific point of view, is a phenomenon of fundamental importance.

The subject is treated as follows: (1) Historical review, (2) the constants of electrolytic water dissociation, (3) review of various methods of procedure, (a) methods and apparatus for the separate production of oxygen and hydrogen; (b) for electrolysis without separation of the gases, and (c) the electrolytic production of oxygen only; (4) applications, and (5) supplementary tabular data.

The work of the author appears to have been very thoroughly done.

The book is well printed and the illustrations are numerous and well executed. W.

Die Normal Elemente und ihre Anwendung in der Elektrischen Messtechnik. Von Dr. W. Jaeger, Kaiserl. Professor, etc. Halle a S. Verlag von Wilhelm Knapp, 1902.

This work treats in a very thorough manner of the voltaic cell, in theory and practice. W.

A Travers la Matière et l'Énergie: par le Dr. F. E. Blaise, Ancien Interne des Asiles d'Aliénés de la Seine, etc. Un volume grand in-8°, 68 photographures dans le texte. Paris: Librairie Ch. Delagrave. (Prix, broché, 12 frs.)

This volume treats, in its first part, of electrochemistry and mechanics; in the second, of matter; in the third, of the formation of bodies and their luminosity; in the fourth, of electricity; in the fifth, of electric induction, and in the sixth and last, of certain conclusions drawn from the foregoing, and of certain philosophical considerations. W.

Publications Received.

Renold High-Speed Silent Driving Chain: The Link-Belt Engineering Company.

Power Plants of the Pacific Coast. (Report from *Trans. N. Y. Electrical Society*). F. A. C. Perrine, D.Sc. From the author.

Normal Construction: "Triebwerke" (Driving-Gears) section 7. W. H. Uhland, Leipzig, Germany. From the author.

The Alasko-Canadian Frontier. Thos. Willing Balch (8vo. pp. 45, with plates). Reprint from the *Journal Franklin Institute*. From the author.

Franklin Institute.

[*Proceedings of the Stated Meeting held Wednesday, October 15, 1902.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 15, 1902.

Vice-President WASHINGTON JONES in the chair.

Present, 240 members and visitors.

Additions to membership since last meeting, 6.

Mr. Edwin S. Balch was elected as a member of the Board of Managers in place of Mr. Benj. Smith Lyman, resigned.

Mr. Cyrus Chambers, Jr., made an interesting address on the art of bread-making, with especial bearing on the so-called "Scientific Bread-Machine," invented by Mrs. Lydia C. Sharpless. The speaker's remarks were profusely illustrated by means of lantern photographs, by the exhibition of the specimen machines, and by an experimental demonstration of the operation of the machine.

The subject was referred to the Committee on Science and the Arts for further consideration.

Adjourned

WM. H. WAHL, *Secretary.*

Committee on Science and the Arts.

(*Abstract of proceedings of the stated meeting held Monday, October 1, 1902.*)

MR. THOS. P. CONARD in the chair.

The following reports were adopted :

(No. 2174.) *Cipher-Code System*.—Willis J. Roussell, New Orleans, La.

ABSTRACT.—This invention is the subject of letters-patent of the United States to applicant, No. 642,721, February 6, 1900, and relates to improvements in the arrangement of a cipher-code index by which the composition of or translation of a cipher message is made more easy and with less liability to error. (A brief statement of the system is impracticable). The conclusion of the sub-committee is that "the improvements devised by applicant for a more perfect method of securing absolute secrecy in cipher messages, and in producing a system of more general application than any which has preceded it, are worthy of recognition." The award of the Edward Longstreth Medal of Merit is made to the inventor. [*Sub-Committee*.—E. A. Scott, Addison B. Burk.]

(No. 2186.) *Tangential Water-Wheel*.—Wm. A. Doble, San Francisco, Cal.

The improvements of Mr. Doble are covered by letters-patent of the United States, Nos. 619,158-9, 633,184, 659,794 and 660,789. These relate in part to an improved form of bucket, and in part to an improved regulating nozzle,

neither of which are susceptible of intelligible description without illustrations. The award of the John Scott Legacy Premium and Medal is recommended. [*Sub-Committee*.—A. M. Greene, Jr., Chairman; Edw. T. Child, L. D'Auria, John E. Codman.]

(No. 2211.) *Siphon Condenser*.—Arthur Pennell, Kansas City, Mo.

ABSTRACT.—The invention consists of a T-shaped steam and water connection, with which the exhaust and circulating water-pipes connect, a condensing chamber in which is placed a spraying device or "water-breaker," and a vertical draft tube through which the gases and circulating water are discharged. The condensing chamber is attached below the T-shaped connection and the draft tube (36 feet long) connects with the bottom of the condensing chamber. The "water-breaker" is supported centrally in the condensing chamber by a stool, the legs of which rest on the flanges into which the draft tube is secured. The circulating water enters through a pipe attached to the top of the T-shaped connection, and the exhaust steam at the side. The column of circulating water, in falling on the cone-shaped water-breaker, is broken into a spray, thus presenting a large condensing surface for the condensation of steam. The air and other gases in the exhaust steam are enmeshed by the turbulent circulating water in the condensing chamber, and are carried downward by the falling column of water in the draft-pipe and discharged into the atmosphere at the bottom of the pipe.

The committee fails to recognize anything particularly new or of special merit in the invention. [*Sub-Committee*.—J. J. DeKinder, Chairman; John E. Codman.]

(No. 2221.) *Electric Elevator for Private Residences*.—Otis Elevator Company, New York.

This report is reserved for publication in full. The John Scott Legacy Premium and Medal is recommended to the inventors. [*Sub-Committee*.—T. Carpenter Smith, Chairman; J. Logan Fitts, C. C. Heyl, Francis Head.]

(No. 2227.) *Electro-Magnetic Geological Balance*.—Estrado, City of Mexico, Mex.

(An advisory report.)

(No. 2231.) *Screw-Cutting Engine Lathe*.—Otto E. Evans.

ABSTRACT.—The designer dispenses with the step-pulley, the variable speed of the spindle being obtained by gearing, the combination of which can readily be changed. The carriage is secured to the front face of the bed, reaching over less than one-half of the upper face. The middle and rear part of the upper face of the bed forms the bed for the tail-stock. The cross-feed of the carriage is positively geared. The cross-slide is moved by a comparatively large but short wormlike screw gearing into a rack. The taper device is attached to the front face of the bed and accomplishes the respective cross movement by means of a rack gearing into a spur wheel secured to the screw shaft. The change in the speed of the bed-screw is accomplished by gear wheels, the combination of which is governed by handles.

The report proceeds to enumerate the comparative advantages and disadvantages of this design, and concludes that the disadvantages far outweigh the possible advantages obtained by the new design. [*Sub-Committee*.—Hugo Bilgram, Chairman; Arthur Falkenau.]

(No. 2233.) *Improved Grate*.—James Reagan, Philadelphia.

ABSTRACT.—A re-investigation to ascertain whether the inventor's claim that the grate would neither warp, welt, nor get out of position in service, was justified by experience.

The Investigating Committee made an extended canvass among the users of the Reagan grate with the view of confirming this claim. All the correspondents from whom advices were received substantiated the claim without reservation. The committee recommends the award of the John Scott Legacy Medal and Premium. [*Sub-Committee*.—James Christie, Chairman; J. M. Emanuel, Robt. D. Kinney, Wilfred Lewis.]

(No. 2236.) *Improved Roll for Crushing and Grinding*.—Gerdt Gerdtzen. (An advisory report.)

(No. 2241.) *Compartment Drawer Bottom*.—John Gowdey, Philadelphia.

This device consists of a drawer bottom having a series of regularly spaced kerfs ($\frac{1}{4}$ inch apart) cut into it, crossing one another at right angles over its entire surface. These kerfs are of sufficient width and depth to receive and support partitions of thin wood, cardboard, vulcanized fiber, etc., by which the drawer may be divided into any number of compartments of any desired size to accommodate all sorts of miscellaneous articles of varying size and shape.

The committee reports that the idea is a meritorious one and that the invention should prove useful in service. The Certificate of Merit is awarded. [*Sub-Committee*.—H. R. Heyl, Chairman.]

(No. 2244.) *Improved Door-Check*.—Eugene I. Blount and Warren H. Taylor.

ABSTRACT.—The object of these imprints is stated to be to enhance the efficiency of door-checks, simplify their construction, and reduce the cost of manufacture; also to provide means whereby the person attaching the device can see at a glance whether the spring is set for a right or left-hand door.

The report finds that the indicator device, and the arrangement of the device on which the spring winds so that it cannot be unwound, are improvements. The details of the apparatus also are thoroughly worked out. The Certificate of Merit is awarded. [*Sub-Committee*.—Ernest M. White, Chairman; L. L. Cheney, Geo. S. Culler.]

(No. 2245.) *System of Control for Electric Motors*.—H. Ward Leonard, Bronxville, N. Y.

This report is reserved for publication in full. The award of the John Scott Legacy Premium and Medal is recommended. [*Sub-Committee*.—Francis Head, Chairman; Arthur J. Rowland, L. F. Rondinella.]

The following reports passed final reading:

(No. 2173.) *The Philadelphia City Hall Tower Clock*.—Warren S. Johnson, Milwaukee, Wis.

(No. 2207.) *Models for Stereometric Representation*.—W. F. C. Morsell, Philadelphia.

(No. 2214.) *System of Gearing*.—Wm. L. Schellenbach, Cincinnati, O.

(No. 2238.) *Improvements in Electric Illumination*.—Luther Stieringer, New York.

Sections.

PHYSICAL SECTION.—*Stated Meeting*, September 25th. Prof. George S. Stradling in the chair. Present, 22 members and visitors. Professor Stradling read a paper entitled "The Ionization of Gases." After some discussion of the subject, the meeting adjourned.

JESSE PAWLING, JR., *Secretary*.

CHEMICAL SECTION.—*Stated Meeting*, October 2d. Dr. William H. Wahl was called to the chair. Present, 18 members and visitors.

Dr. J. Merritt Matthews, Philadelphia Textile School, made an informal communication on "The Scientific and Industrial Development of Artificial Indigo," with an exhibition of specimens, and experimental demonstrations. The communication was referred to the Committee on Publication. Adjourned.

WM. H. WAHL, *Secretary, pro tem*.

ELECTRICAL SECTION.—*Stated Meeting*, October 9th. Mr. Thos. Spencer in the chair. Present, 70 members and visitors.

Mr. Joseph Sachs, of the Johns-Pratt Company, Hartford, Conn., read a paper on "Electric Fuse Protective Devices," which was illustrated by the exhibition of a large number of specimen fuses of this type, and by an instructive series of experimental demonstrations. Messrs. Carl Hering, C. J. Reed, Francis Head and others discussed the paper, which was referred for publication in the *Journal*.

RICHARD L. BINDER, *Secretary*.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, October 16th. Mr. James Christie, Chairman, *pro tem*. Present, 65 members and visitors.

The meeting was devoted to the discussion of the subject of "Multiple Voltage Systems for the Speed-Control of Tools." Messrs. James Christie, Charles Day, Francis Head and others participated.

DANIEL EPPELSHEIMER, JR., *Secretary*.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, held October 23d, 1902. Mr. Martin I. Wilbert in the chair. Present, 65 members and visitors.

Mr. Fred. E. Ives presented a communication describing an improved binocular microscope of his invention, and exhibited the apparatus.

The device consists of a simple attachment applicable to any short-tube microscope, by means of which it can readily be changed to a satisfactory binocular.

Mr. Ives also called attention to some improvements that he had made in his microscopic camera-box that is interchangeable with the camera on the stand. An interesting feature of this camera is the fact that the resulting prints do not need to be separated and reversed in the subsequent mounting, this being provided for in the prisms dividing the eye.

Mr. Ives then called attention to his "Parallax Stereogram," which was on exhibition.

Mr. W. W. Canby followed with an interesting series of lantern photographs taken during a recent trip through Alaska.

M. I. WILBERT, *Secretary*.

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CHEMICAL SECTION.

Stated Meeting, held Thursday, February 27, 1902.

The Analytical Methods for Carbohydrates as Applied to Foods and Feeding Stuffs.

BY WILLIAM H. KRUG,
U. S. Department of Agriculture.

(Concluded from p. 366.)

Large quantities of maple syrup are continually found on the market which consist of glucose mixed with a little genuine syrup and malted cane-sugar, the whole mass being flavored with an extract of hickory bark. The testimony given before the Committee on Manufactures of the United States Senate revealed to some extent the magnitude of this form of adulteration. The method of detection is in every respect similar to that described for table syrups. Maple syrups are sometimes adulterated by the addition of cane-sugar, and it is impossible to detect this adulteration, as the sugar of the cane and the maple are identical. In

cases of this kind the purchaser has to rely solely upon his experience with reference to the taste and flavor of the genuine product. The same may be said concerning maple-sugar which has suffered an addition of ordinary yellow sugar.

Honey is probably one of the most extensively adulterated foods, the usual adulterant being glucose. The deception is in many cases carried to such a point that the product offered as "genuine" consists totally of glucose, to which the manufacturer has added a piece of drained honeycomb to render the fraud more acceptable. A certain quantity of glucose is also frequently added, because it prevents the subsequent crystallization common in pure honeys and assures a product which is at all times clear and transparent.

Honey is as a rule levorotatory, the chief sugar present being invert-sugar, and a dextrorotatory product should be viewed at once with suspicion, as the dextrorotation may be due to the presence of an excessive amount of cane-sugar, glucose or both. It must be remembered, however, that honeys of known purity have been found which are dextrorotatory, noticeable instances being the pine-tree honeys, which are produced by bees feeding on the exudation formed on pines by a certain fungus. The dextrans contained in these honeys resemble those of commercial glucose very closely, so that a distinction is practically impossible. Fortunately, these products generally have a very unpleasant odor and an acrid taste and they are probably never used as a food, although their existence has frequently been taken advantage of by the defense in prosecutions for adulteration. According to Beckman the presence of glucose in honey may be detected qualitatively by the addition of methyl alcohol and a solution of barium hydroxid to the diluted honey. In the presence of glucose a weighable precipitate is obtained, while with a pure honey it is only slight. Methyl alcohol alone may be used for this test when pure honey yields only a slight flocculent precipitate which settles rapidly and is only faintly colored by an iodine-potassium iodide solution, while with glucose there is obtained a gummy deposit which attaches itself to the sides of the

beaker and gives with the iodine-reagent the reddish violet-reaction characteristic of the amylo-erythroextrins. Naturally, both of these tests fail when a technically pure dextrose is used. The fermentation method may also be applied to honeys. Pure honey yields by this method a final solution which often possesses a slight dextrorotation, and authorities differ as to the allowable maximum. In any event it should not exceed $+3^{\circ}$ when a 10 per cent. solution is polarized in a 200-millimeter tube. As a further proof, the final solution may be inverted with hydrochloric acid, when pure honeys will show only traces of reducing sugar; while honeys adulterated with glucose exhibit a correspondingly large amount of dextrose.

The addition of cane-sugar to honey is rather difficult to prove, as a normal honey may contain as much as 10 per cent. The presence of cane-sugar is frequently due to the fact that beekeepers use it as a food for the bees during the winter season. In Europe this is considered an adulteration. Comparatively small amounts of cane-sugar reduce the normal levorotation of the honey while larger amounts cause a dextrorotation. All such honeys exhibit after inversion an increased levorotation or a change from dextro- to levorotation. In the absence of glucose the quantity of sucrose is readily determined by the polarization or gravimetric determination of the invert-sugar before and after inversion. Pure honeys contain usually about 70 per cent. of invert-sugar, and the difference between invert-sugar before and after inversion never exceeds 8 per cent., while in honeys mixed with cane-sugar, this difference amounts to as much as 45 per cent. Molasses is rarely used in the adulteration of honeys and may be detected by the method given for cane-sugar. Beckmann has suggested a qualitative test depending on the addition of a solution of lead subacetate in methyl alcohol to the honey, sufficiently diluted, so that the lead subacetate alone does not produce a precipitate. In the presence of molasses a weighable precipitate is obtained, while pure honeys are at the most rendered only opalescent.

Rare cases are recorded where honeys have been adul-

terated by the addition of starch or flour. This is easily detected by treating the suspected sample with 70 per cent. alcohol and collecting the insoluble residue on a filter, when it may be examined microscopically or subjected to further analysis if a quantitative result is required. Instances are also known where the honeys have received an addition of invert-sugar. It is impossible to detect this form of substitution with certainty, owing to the fact that the adulterant is identical with the sugar normally present in honey.

Fruit Products.—Under this general heading are included fruit juices, jellies, jams and marmalades.

Fruit juices and syrups are subject to two forms of adulteration which can be proved by an estimation of the sugars. The former are frequently diluted with water whereby the composition of the syrups, of which they form the basis, is affected, and the latter receive, similarly to honey, etc., an addition of glucose. Unfortunately, the average composition of the various fruit juices is not sufficiently well known to establish appropriate standards. Huckleberry juice is extensively used in Germany and the composition has been studied by Spaeth,* who found that in a syrup prepared from a pure juice, the non-sugars, *i. e.*, the difference between the total solid matter and total sugar, never fell below 1.3 per cent., and he therefore concludes that all syrups whose non-sugars are found to be below this minimum have been prepared from a diluted juice.

The addition of glucose to fruit syrups is very generally practised, both on account of the low price of the adulterant and because its addition permits the use of a much smaller quantity of the most valuable constituent—the fruit juice itself. The latter is due to the fact that even so small an addition as 5 to 10 of glucose, to 100 of cane-sugar, prevents the subsequent crystallization and permits so-called cold mixing. In a pure syrup the same result is accomplished by using a large quantity of fruit juice and evaporating

* "Ztschr. für Untersuchung der Nahrungs- u. Genuss-mittel," 4, 97; 4, 921.

the mixture to the proper density, but this is naturally more expensive. The addition of glucose furthermore allows the use of less solid matter, because it imparts to the finished product a viscosity similar to that prepared from fruit juice and cane-sugar used in larger quantities.

The carbohydrates naturally present in a fruit syrup are cane-sugar and invert-sugar. The latter is in part introduced with the fruit juice and the remainder is due to the inversion of the cane-sugar subsequent to the manufacture. The presence of glucose can therefore be detected by the polarization before and after inversion and by the fermentation method. Spaeth has shown that pure huckleberry syrups show, after inversion of a 10 per cent. solution, a levorotation varying from $2^{\circ} 20'$ to $2^{\circ} 44'$. A dextrorotation after inversion or after fermentation is therefore positive proof of the addition of glucose. It must be noted, that in the preparation of the solution for polarization, a sufficient excess of lead subacetate must be added to insure the complete removal of malic acid and the malates, which influence the polarization, in that they are either levo- or dextrorotatory, depending on the concentration of the solution. Spaeth claims that an approximate estimate of the quantity of glucose present can be obtained by heating the fermented solution with hydrochloric acid and determining the resultant dextrose, it being assumed that the glucose contained from 30 to 40 per cent. dextrin. Owing to the wide variations in the composition of commercial glucose, this can be at the most only a very rough approximation, and for general purposes the mere proof of the adulteration is sufficient.

A determination of the cane-sugar present in a fruit syrup furnishes a valuable indication of the age of the product, as this sugar undergoes in time a slow inversion, owing to the presence of organic acids.

Jellies and Similar Products.—When pure, these foods are always prepared from the pulped fruit with the addition of a suitable quantity of cane-sugar. It is highly probable, however, that few of the products to-day on the market, especially the cheaper grades, are manufactured in this

manner. The most common form of adulteration is, as usual, the incorporation of varying quantities of glucose. Another form of sophistication which is very extensively practised in the preparation of the lower grades of jellies is the use, as a basis, of an apple-jelly made from the peelings and cores. This is mixed with glucose and then colored and flavored to resemble the fruit from which the finished product is claimed to be derived. A certain quantity of cane-sugar may also be added to increase the sweetness, glucose being from three to four times less sweet than sucrose. The use of apple-jelly may be detected by a microscopical examination for starch, the apple being the only fruit which contains starch in appreciable quantities. The value of this test is, however, limited by the fact that the starch disappears very rapidly with the ripening of the fruit.

The color of the diluted jelly is first destroyed by treating it at the boiling-point with a little diluted sulphuric acid and potassium permanganate, which does not attack the starch, and then testing with iodine. Excessive quantities of starch will naturally show that it has been added directly; but this form of adulteration is not generally resorted to.

Confectionery.—Probably one of the most extensive uses of glucose is in the manufacture of candies and confections, and its addition can hardly be styled an adulteration. Other constituents are sucrose, invert-sugar and gum, and a separation of these carbohydrates is very difficult, and possesses no value in the judgment of the materials. Glucose is used most largely in the manufacture of transparent candies, as these cannot be prepared with cane-sugar.

Glucose and Dextrose.—The most recent German food-regulations permit the addition of glucose or dextrose to foods and wines, provided they are technically pure, or, in other words, do not contain more traces of sulphuric acid or non-fermentable constituents. These restrictions are due to the fact that the non-fermentable substances, among which may be mentioned amylin and gallisin, are dangerous to health, but it must be stated that this point has not been

definitely decided. Analyses of glucose or dextrose are therefore frequently required which, with reference to the carbohydrates, consist of a gravimetric determination of the dextrose before and after treatment with hydrochloric acid, the latter converting dextrin into dextrose. The dextrose derived from the dextrin is obtained by difference and calculated to dextrin by the factor 0.9. The non-fermentable constituents are determined qualitatively by the fermentation method. When these are present it is necessary to deduct the dextrose which they yield by inversion from the total to obtain the true percentage of dextrin.

Dextrose generally contains from 65 to 75 per cent. of dextrose and 5 to 15 per cent. of dextrin and unfermentable bodies, while glucose contains from 35 to 45 per cent. of dextrose and about 40 per cent. of dextrin, etc.

Beer.—The most important material used in the manufacture of beer is the barley which contains the starch from which the sugar necessary for the fermentation is derived. A barley containing a large percentage of starch is therefore preferred by brewers, and it is customary to determine the amount present as a means of judging the value of the cereal. The analysis should always be made by the diastase method, whereby the error which is introduced by the hydrolysis of the insoluble carbohydrates, when methods depending on direct treatment with acids are used, is avoided.

During the malting process, a ferment, diastase, which has the property of converting starch into sugar, in the presence of water, is formed in the grain. To properly judge the malt, it is therefore necessary to determine the time required for complete saccharification. The method used is as follows:

Fifty grams of the ground malt are mixed with 200 cubic centimeters of water at 45° C. and kept at this temperature for an hour. The temperature is then increased to 70° C. at the rate of 1° C. per minute, and the mash is kept at this temperature and tested with an iodine solution every five minutes until only a light red or yellow to brown reaction is obtained. The time of saccharification is calcu-

lated from the moment when the temperature reached 70° C., and the mash must be stirred slowly during the whole process. The mash is then mixed with 200 cubic centimeters of water, cooled rapidly to about 15° C., the weight increased to 450 grams by the addition of water and the wort obtained by filtration. The density of the wort is determined at 15° C. and the total extract calculated by means of a table prepared by Windisch.* The total extract in the air-dry malt is then calculated according to the formula

$$p = \frac{e}{100 - e} \times (W + 2H)$$

in which p = total extract in air-dry malt,

e = total extract in the wort,

W = moisture in the malt,

H = weight in grams of the water added.

The sugar is determined gravimetrically as maltose in the diluted wort, using Wein's method, and the proportion of maltose to non-maltose is then obtained. The time of saccharification varies from fifteen to forty-five minutes for a good malt. The total extract should equal from 74 to 82 per cent., and the proportion of maltose to non-maltose should be about 1 : 0.5.

The carbohydrates present in beer are traces of maltose which have escaped fermentation and achroodextrins [Achroodextrin I and II (Lintner) Achroodextrin III (Prior) and possibly also Achroodextrin IV, Maltodextrin II (Baker and Link)] all of which exert a specific reducing action on an alkaline copper solution.

A determination of the maltose, therefore, always includes the reducing value of the dextrins, but it has become customary to simply determine the total reducing power of a beer, stating this in terms of maltose.

The dextrins are determined by inversion with hydrochloric acid, the total dextrose being estimated and the dextrose equivalent to the maltose previously found being deducted (maltose $\times 1.052$ = dextrose). The remaining

* Bujard and Baier, "Hilfsbuch für Nahrungs- mittelchemiker," p. 198.

dextrose is calculated to dextrin by the factor 0.925. The amount of dextrans present in beers generally amounts to about one-half the total extract.

Barley substitutes are frequently used, especially in the manufacture of light beers, and among these may be mentioned rice and glucose. It is very doubtful if the substitution of another cereal for barley can be detected with any certainty. The examination for glucose is based, as in all other cases, where this adulterant is used, on the presence of the unfermentable constituents. The method of Haarstick is generally used, according to which the beer is evaporated to a thin syrup, from which all constituents precipitable by alcohol are removed, the alcohol recovered from the filtrate and the residue dissolved in water and fermented.

Malt Extracts.—These preparations have in recent years achieved considerable reputation as dietetic foods and are extensively manufactured. Their nutritive value depends chiefly on the soluble carbohydrates present, which vary with the degree of sacchrification to which the malt has been subjected. According to Dieterich, a good malt extract should contain from 62 to 67 per cent. maltose and from 2.5 to 4 per cent. dextrin. The maltose is determined with sufficient accuracy gravimetrically as described under "beer." The dextrin is most conveniently estimated by deducting the sum of maltose, protein and ash from the total solid matter. It may also be determined by precipitation with an excess of absolute alcohol. The maltose is precipitated at the same time and the precipitate must be dissolved in water and the reduction determined before and after inversion, the dextrin being obtained by difference.

The addition of cane-sugar to malt extracts should be considered an adulteration. The quantity present, when such an addition has been made, is such that it can be estimated with sufficient accuracy by determining the reducing sugar before and after inversion, although absolute results are impossible, owing to the presence of dextrin, which also suffers at least partial hydrolysis.

Wines.—The proper judgment of wine, even with the aid

of a complete analysis, is one of the most difficult problems presented to the food chemist, and requires an extensive experience and thorough knowledge of the composition and characteristics of the various kinds of wines, and of the variations existing between successive vintages of the same wine. The chief application of the results obtained by the determination of the sugars present in a wine is the detection of the method of treatment known as "gallizing," which is extensively practised by many winemakers. The composition of the must obtained in poor grape years is often such, with reference to the amount of sugar and free acid present, that a palatable wine can only be obtained by adding a certain quantity of sugar, either in the form of cane-sugar, invert-sugar or pure dextrose. A normal must will contain about 24 per cent. of sugar and 5 per cent. of free acid, but in poor years the latter will amount to as much as 16 per cent., and this will then be decreased by dilution with water, the quantity of sugar necessary to proper fermentation being added. The sugar required is usually calculated by multiplying the sugar-content of the original must by a factor obtained by dividing 100 by the volume of the diluted must. The German laws relative to the addition of sugar for the purpose of increasing the alcohol-content and masking the acidity of a wine, permit the use of technically pure cane or beet-sugar (not more than 1 per cent. non-sugars), of invert sugar prepared from technically pure cane or beet-sugar and not containing more than 20 per cent. of moisture, and of starch sugar (99.64 per cent. dextrose), but the addition is in general limited so that 100 cubic centimeters of wine shall not contain less than 1.50 grams total extract, 1.10 grams extract less non-volatile acids, 1.00 gram extract less total free acids, and 0.14 gram ash.

Frequently the "gallizing" is carried to the point where the manufacturer is forced to increase the total extract by the addition of gum or dextrin to the finished wine. The carbohydrates, which must therefore be determined in a wine, are invert-sugar, sucrose and dextrin, and, if indicated, an examination for the non-fermentable constituents of commercial glucose.

Another form of adulteration which is extensively practised and frequently very difficult to detect, is the preparation of wines from the pressed grapes, called petiotization. The pressed grapes are mixed with a solution of sugar, to which some tartaric acid has been added, and are then fermented. The resulting alcoholic fluid is improved as required by adding acid, glycerol, coloring matter, etc. These wines often have a good color and bouquet, and in many instances cannot be distinguished from pure wines except by a very thorough and careful determination of all constituents. A determination of the sugars is generally of very little value, as it gives no clue as to the source of the wine. The use of commercial glucose can be detected by the polarization after fermentation.

A pure, fully fermented wine is generally optically inactive or only slightly levorotary, a dextrorotation being a rare exception. The direct polarization is, however, not positive proof of the absence of an adulteration, as sucrose and invert-sugar or the non-fermentable dextrorotatory constituents of glucose and invert-sugar may be present in such proportions that the wine exhibits no rotation. The former condition is detected by determining the invert-sugar gravimetrically before and after inversion, the invert-sugar due to the sucrose being obtained by difference and calculated to sucrose by the factor 0.95. In the latter case, it is necessary to subject the wine to fermentation according to the following method:

"De-alcoholize 200 cubic centimeters of wine by evaporating to about one-fourth its volume, and add enough water to the residue to make its sugar-content less than 15 per cent. Add 2 or 3 grams of compressed yeast; let stand at about 25° for three to four days, when fermentation will be complete.

"Evaporate the fermented liquid in a porcelain dish to a thin syrup, after the addition of a little sand and a few drops of a 20 per cent. solution of potassium acetate. To the residue add 200 cubic centimeters of 90 per cent. alcohol with constant stirring. Separate the alcoholic solution by filtration and evaporate until about 5 cubic centimeters

remain. Mix the residue with washed boneblack, filter into a graduated cylinder and wash until the filtrate (cooled to 15°) amounts to 30 cubic centimeters. When the filtrate shows a dextrorotation of more than 1.5° it indicates the presence of the unfermentable constituents of commercial glucose."

Other conclusions with reference to the polarization of a wine are:

A dextrorotation may be due to cane-sugar which was added previous to fermentation. This may be detected as just described, or by means of a polarization before and after inversion; but when the invert reading exceeds $+0.3$ Wild, the presence of glucose is indicated and the wine must be fermented and again polarized.

A slight levorotation may be normal and may also be due to the presence of cane-sugar, a portion of which has been changed into invert-sugar by the organic acids always present in wine. A wine of this kind will show an increased rotation after inversion.

A high reducing power may be due to the presence of invert-sugar, of dextrose, or of both. When only invert-sugar is present, the wine will be levorotatory—dextrose alone will produce a dextrorotation; and when both are present, the proportions may be such that the wine is optically inactive. The last condition may be detected by polarizing the wine at 87° C., at which temperature the rotatory power of invert-sugar practically equals 0, while the dextrose is not affected.

The general conclusions to be drawn from these data may be summarized as follows:

(a) When the wine contains less than 0.1 gram reducing sugar in 100 cubic centimeters, and is either optically inactive, slightly levorotatory, or has a dextrorotation not exceeding 0.3° , the absence of sucrose and of commercial glucose is proved.

(b) When the wine contains less than 0.1 gram reducing sugar in 100 cubic centimeters and has a dextrorotation of 0.3° — 0.6° , the presence of dextrin is indicated and the wine should be examined accordingly, and also for the unfermentable constituents of commercial glucose.

(c) When the wine contains less than 0.1 gram reducing sugar in 100 cubic centimeters and has a dextrorotation of more than 0.6° , it must be examined for dextrin and, if this is present, also for the unfermentable constituents of glucose. When dextrin is absent the wine contains the dextrorotary residue due to the addition of glucose before fermentation.

(d) When the wine contains more than 0.1 gram reducing sugar in 100 cubic centimeters, it must be examined for glucose.

Dextrin or gum arabic are sometimes added to wines for the purpose of increasing the total extract so as to bring it within the limits found in the normal product. An addition of this kind can be detected qualitatively by mixing the wine with two and one-half times its volume of 96 per cent. alcohol which, in the presence of gum or dextrin, causes a tough gummy precipitate. The adulteration may then be determined quantitatively by concentrating the wine to a small volume and precipitating with an excess of alcohol. The precipitate is collected, re-dissolved in water and inverted by means of hydrochloric acid, the reducing sugar being determined in the final solution and calculated to gum or dextrin by the factor 0.9. Pure wines will yield only traces of reducing sugar.

Sweet Wines.—The judgment of sweet wines is an extremely unsatisfactory subject, owing to the variety of methods by which they are prepared; and a discussion of the composition of the many types found on the market is impossible within the scope of this paper, as may be shown by quoting the general principles followed in the preparation of these wines, which are given by Elsner, "Die Praxis des Chemikers," p. 396, as follows:

1. (a) By fermentation of the must obtained by concentration of the juice of the partially dried grapes.

(b) By fermentation of must prepared by the extraction of raisins with must or diluted wine.

(c) By fermentation of a must which has received an addition of concentrated must.

(d) By the extraction of raisins with wine.

(*c*) By mixing must with wine.

2. By the addition of alcohol to the must while in the process of fermentation.

3. By the addition of varying quantities of cane-sugar, dextrose or invert-sugar to the must.

In the German wine laws these wines have appropriately been given a separate position and are styled "dessert wines," whereby they are distinguished from "medicinal wines," the latter being specially described as the product from pure grape juice, while in the former the use of raisins is not considered an adulteration. All sweet wines, with the exception of such wines as Malaga, sherry and Marsala, contain large quantities of reducing sugar, owing to incomplete fermentation, and the chief point to be decided by the chemist, with reference to the carbohydrates present, is the addition of cane-sugar, invert-sugar or glucose, it being manifestly impossible to express any opinion as to the origin of the wine, even with the aid of most complete analytical data. The polarization of the wine before and after inversion has very little value. Invert-sugar cannot be detected in this manner, as there is no change in the polarimetric reading. Cane-sugar can only be found in isolated cases, because it suffers rapid inversion during the fermentation of the must, although its presence may sometimes be shown when it has been added to the finished wine. The addition of glucose is detected by the polarization after fermentation.

According to König, the relation between the dextrose and levulose in such wines permits certain conclusions, these being present in a pure wine in practically the same proportions as in invert-sugar. A large excess of levulose indicates that the wine has been made by the fermentation of a concentrated must or by the interruption of the fermentation by the addition of alcohol. An excess of dextrose, on the other hand, may be due to the subsequent addition of an aqueous extract of raisins or grapes. A definite conclusion can, however, not be reached when these sugars are present in approximately the same amounts or when the levulose is only slightly in excess. Similarly,

the relation does not serve as an indication of the addition of cane-sugar or glucose previous to fermentation, as the dextrose derived from the former by inversion and that present in the latter are fermented as readily as the dextrose of the must.

Distilled Liquors.—The only addition to liquors which is of especial interest in connection with the subject under discussion is the use of caramel to impart an appearance of age to the beverage, and of small quantities of sugar to improve the palatability. This practice can hardly be considered an adulteration, except in the case of cognac, when the total extract should never exceed 0.5 per cent. A determination of the extract is the best means of detecting the use of caramel or sugar, as it can only consist of the substances extracted from the wood of the casks and the materials added for the purposes above stated. The use of caramel necessarily always introduces a small quantity of sugar, and the extract obtained from a colored cognac or sweetened liquor develops a very characteristic caramel odor when heated. Amthor's method,* which depends upon the precipitation of the caramel and subsequent conversion into caramelphephenylhydrazin, may be used, although the accuracy of the method appears doubtful when we consider the exceedingly small amounts of caramel necessary to obtain the required depth of color. Thus, Fresenius found that a dark-colored rum contained only 0.34 to 0.68 per cent. extract. It is therefore evident that the addition of sugar or caramel to distilled liquors can be prevented most satisfactorily by fixing a maximum limit for the total extract present, but the composition of pure distilled liquors requires considerable further study before these can be established.

Omeis† has found several cognacs which were prepared with the addition of glucose; this being shown by the polarization after removal of the alcohol and fermentation with

* Elsner: "Die Praxis des Chemikers," Ed. 7, p. 360.

† Omeis: "Ztschr. für Untersuchung der Nahrungs und Genussmittel," 1899, p. 703.

yeast. Cognacs are often found which possess a slight dextrorotation due to the presence of cane-sugar, but these all become levorotatory on inversion.

Coffee.—Cheap coffees are often glazed by the addition of sugar, dextrin or solutions of these substances during roasting, whereby imperfections are covered and the bean is made to resemble a more expensive grade. In some respects, however, the judicious glazing of coffee cannot be considered an adulteration, as a coating of caramel without doubt retains the volatile constituents of the bean and improves the aroma and taste of the beverage. The use of such substances for glazing is detected by shaking the coffee with cold water (20 grams coffee with 500 cubic centimeters of water at 15° C. for five minutes), and determining the quantity of organic matter removed by evaporating an aliquot portion of the filtered solution. The amount of sugar added by caramelization should not exceed 3 per cent.

The number of coffee adulterants offered either as such or in the form of mixtures with genuine coffee is legion, and cheaper grades of both whole and ground coffees sold in the American market are frequently adulterated—the former receiving an addition of artificial beans, while the latter are mixed with chicory, fig-coffee, crushed roasted cereals, etc. In most cases, when adulteration of this kind is suspected, the experienced microscopist has no difficulty in establishing its existence and the identity of the material, although he should always have at hand, for comparison and confirmation, a series of preparations representing the substances most frequently used for this purpose.

In some cases the microscopical examination may be profitably combined with a chemical analysis; thus, the presence of chicory may be detected by a determination of the reducing sugar present. Pure coffee contains only small amounts (0.5 per cent), while in chicory almost a third of the water-soluble constituents consists of reducing sugar, which is equivalent to about 20 per cent. Roasted cereals contain very little reducing sugar, but they may in turn be easily detected by determining the sugar found by hydrolysis; coffee yielding, on an average, 25 per cent., chicory 22 per cent. and roasted cereals 75 per cent.

The varying preparations which are sold extensively for the purpose of supplying a coffee-substitute which possesses the flavor of the genuine beverage, without its alleged harmful effects on the human system, are not to be despised. They are stimulating, nutritious and cheap, and should in time become the favorite drink of the poorer classes. Their value depends on the extent to which they possess the aroma and taste of genuine coffee and on the soluble carbohydrates present. If required, the soluble and insoluble carbohydrates may be determined as described under "Infant Foods."

Cacao.—The seeds of *Theobroma cacao* serve as a basis for a variety of important food preparations, chief among which are cacao, cacao powder and sweetened chocolate. Pure cacao is prepared by roasting the husked bean and pressing the mass into cakes while hot. Cacao powder is made in a similar manner; about one-half of the fat being removed by pressure. The ordinary sweet chocolate consists of cacao mixed with varying proportions of starch and flavored usually with vanilla. It must be noted, however, that a guaranteed pure sweet chocolate should contain no starch other than that normally present in the cacao.

The chief adulteration of these various products consists in the addition of ground cacao shells or of starch or flour, a practice very generally applied to the cheaper grades. A careful preliminary microscopical examination should always be made whereby the presence of foreign starches is detected, the starch granules of the cacao being smaller than those of almost all cereals. The microscope may also be used in determining roughly the quantity of foreign starch present. For this purpose a number of preparations are made, using mixtures of pure cacao with 10, 15, 20 and 25 per cent. of starch, and the cacao to be examined is compared with these by counting the number of foreign starch grains present on a certain space. Zipperer has been able in this manner to detect the addition of one part of starch to 5,000 parts of cacao. When the addition of starch or flour has been shown microscopically, it may be determined by the diastase method after removing the fat. With sweet

chocolate it is naturally also necessary to remove the sugar, which is accomplished by extraction with 80 per cent. alcohol. The final result must be decreased by 15, which represents the average percentage of starch present in a pure cacao. The 80 per cent. alcohol extract may be used for the sucrose determination by removing the alcohol, dissolving the syrupy residue in water, and polarizing after clarification.

In connection with the detection of an addition of ground cacao-shells, the determination of the crude fiber or cellulose is often of value. A pure cacao contains from 3 to 4 per cent. or less, while the shells contain as much as 15 per cent. It is evident, therefore, that an addition of 10 per cent. of shells will increase the cellulose in the product by about 1.5 per cent. The addition of ground shells is the most frequently practised and at the same time most despicable fraud, as the shells have neither commercial nor nutritive value. Their presence must, without exception, be ascribed to intentional addition, as the separation of the bean from the shell is practically complete in factories equipped with modern machinery.

In judging a sweet chocolate, we may assume that a pure product contains, on an average, 50 per cent. of fat and non-sugars, and a figure much in excess of this indicates the addition of starch or flour, since it is possible to incorporate as much as 6 parts of flour for each part of fat present without materially changing the external appearance of the chocolate.

Spices and Condiments.—The adulteration of these necessary adjuncts to human foods is limited almost totally to the ground materials and is here very generally practised. In general, the analyst depends on a microscopic examination to detect the addition of foreign substances and does not attempt a quantitative analysis, it being sufficient to determine the presence and character of the fraud. An extensive trade is carried on in so-called "fillers," which consist of starch, flour, ground cereals and various other substances colored and flavored so as to resemble the spice with which they are to be mixed. Considerable experience

is naturally necessary to distinguish and identify the various materials which may have been added, as well as a knowledge of the characteristics of the starch granules which occur *per se* in the genuine spices.

Cinnamon is frequently adulterated with flour, bread-crumbs and sugar. The starchy substitutes are easily detected by means of the microscope. The presence of sugar may be shown by shaking the ground cinnamon with ether when the sugar sinks to the bottom. It may be determined quantitatively by polarizing an aqueous extract.

Cloves are occasionally adulterated by adding the so-called "mother cloves," *i.e.*, the partially ripe fruit of the clove-tree. These are recognized by the large amount of starch which they contain and which resembles turmeric starch very closely.

Pepper.—In the opinion of the dishonest spice-miller, almost any substance will serve as an adulteration of pepper. The pepper-shells and stems are extensively used, as also various flours, ground acorns, oilcakes, seeds, ground nutshells, etc., and the variety and extent of the sophistication is such that the microscopical examination is extremely difficult.

According to Lenz,* the addition of pepper-shells may be detected by determining the reducing sugar obtained by hydrolysis with hydrochloric acid. The various genuine peppers yield from 32 to 63 per cent., while pepper-shells only yield 11 to 13 per cent.

Jumeau recommends a determination of the cellulose for the detection of pepper-dust and pepper-stems. He found the black peppers to contain about 12 per cent., the white peppers about 4 per cent., pepper-dust, 28 per cent.

Paprika is frequently adulterated with various flours, bran, bread-crumbs, etc., which may be detected with the microscope.

Mace receives an addition of curcuma, flour, etc. Sugar may be detected qualitatively by shaking the spice with chloroform and determined quantitatively by polarization of an aqueous extract.

* Lenz, "Ztsch. f. anal. Chem.," 1884, 501.

Nutmegs are rarely sold in the ground condition. Excellent imitations have, however, been found which consisted of bread, clay and oil of nutmeg, and were covered with flour or chalk to make the resemblance more perfect. A microscopic examination readily reveals this fraud.

Saffron is often weighted with mineral substances, honey, sugar, gum or dextrin being added to obtain a more intimate mixture. The binding material can be removed by washing with lukewarm water and identified by means of the usual methods.

Cardamom seeds, when ground, are frequently mixed with ginger, flour, sugar, etc. The presence of ginger may be detected by the shape and size of its starch, the starch grains of pure cardamom seeds being extremely small.

Ginger is frequently adulterated with flour, sugar, etc. The methods of detection are similar to those previously given.

Mustard.—The chief adulteration of both ground and prepared mustard is the addition of rice or wheat flour, the color of the mixture being improved by the judicious use of turmeric. Such additions are readily detected by means of the microscope, as genuine mustard contains no starch. When a quantitative determination is desired, the analyst must take into consideration the possible presence of sugar, which is a constituent of some mixed mustards. This is most conveniently removed by diluting the mustard with water and washing thoroughly on a hardened filter, the starch being determined in the insoluble residue.

The presence of a certain quantity of flour in such mustards cannot always be styled an adulteration, as it may be added for the purpose of attenuating the zest of the condiment and in obedience to the demands of the purchaser. The manufacturer should, however, be forced to declare the extent of such addition, so as to prevent fraud; and it furthermore appears more proper to allow the consumer to determine the degree of dilution he desires and practice it himself. In ground mustard the presence of flour should always be considered an adulteration.

Other spices might be mentioned, but the materials used

for adulteration and the methods employed for their detection are practically the same as I have just described.

In conclusion, it is necessary to say that even with the amount of work done in the past, the results of which I have attempted to recapitulate in this paper, the study of foods with reference to the carbohydrates present has in many respects not kept pace with the advances made in other lines of food chemistry. Much future investigation will be required before the results obtained can be applied with absolute certainty, and until this end is attained the chemist will frequently meet with cases where the methods so far known have been shown to yield only approximate results, and where he is forced to rely upon his judgment in the choice of that method of examination which is most appropriate for the immediate purpose. In many cases the chemist is not justified in restricting his work to such precise determinations as are associated with other lines of other analytical chemistry, even though methods which permit this may be known. The food chemist must always take into consideration the fact that the exigencies of his work require methods capable of being carried out with such rapidity that they yield results, which, while they are only approximately correct, still serve the object of the investigation with perfect satisfaction. It must not be forgotten, however, that frequently cases arise in which he is required to apply exact methods. A wine may contain all the constituents usually found in the pure product and, furthermore, in fairly correct proportions, and may still be adulterated or purely artificial, when only a painstaking analysis of the ash will yield the information desired. It is evident, therefore, that the formulation of acceptable methods for all food analysis is an extremely difficult matter, and must be carried out with great caution, so as to avoid all errors which would naturally at an early date render the method inoperative. In Germany this work has been entrusted to a commission of experienced chemists, and the result of their labors is shown by the fact that the present food law contains specific regulations concerning the methods of food analysis, and limits with reference to certain constit-

uents as regards wine, butter substitutes, fats, poisonous dyes and utensils. It is to be hoped that a united effort may soon be made in this country whereby the adulteration practised so openly and extensively to the detriment of both the health and pocket of the public may be severely restricted if not completely stamped out. In this connection, exact methods for the determination of the carbohydrates and the proper interpretation of the results obtained will be of supreme value, and are a worthy subject for painstaking investigation.

BUREAU OF CHEMISTRY, UNITED STATES DEPARTMENT
OF AGRICULTURE, Washington, D. C.

STASSANO ELECTROMETALLURGICAL PROCESS.

This process aims at replacing the heat of combustion of the coal in the ordinary metallurgy of iron by the electric arc, and should be advantageous in countries where fuel is costly and water-power cheap. The roasted and powdered ore is first of all passed through a magnetic separator in order to prepare a material rich in iron. This is then analyzed and the amount of carbon required for its reduction, calculated. The mineral is then mixed with the necessary amount of powdered wood charcoal and tar, whose percentage of carbon is known, and a slag-forming material, and made into briquettes. These are then introduced into the electric furnace. The chemical reaction is at first very lively, but becomes quieter after a time, and the amount of heat necessary continually decreases. A furnace of 150 horsepower yields in one and one-half to one and three-quarter hours nearly 30 kilograms of wrought iron. By varying the amount of carbon added according to the previously made analysis, it is possible to prepare a cast-iron with a certain fixed percentage of carbon. The plant at present working is at Darfo in the province of Brescia in Italy, and uses a fall of 30 meters of 5 cubic meters water per second.

FUTURE OF THE GAS-ENGINE.

In the opinion of Professor Thurston the gas-engine is a formidable rival of the steam-engine, and is capable of further development. Each has given a horse-power for about one pound of coal, and the efficiency of both, between the coal pile and the point of delivery, is about 20 per cent. The steam-engine, he says, has so nearly reached its limit that further progress under commercial conditions would seem to be very slow, but its range may be increased by employing very high pressures and superheating combined with them. In Sibley College work, 1,000 pounds per square inch have been used, and Professor Thurston expresses the view that twice that pressure may be successfully used eventually, or with sufficient experience in its management. These factors would raise the efficiencies nearly 50 per cent. and reduce the coal per horse-power hour to about three-fourths of one pound.

CHEMICAL SECTION.

Stated Meeting, held Thursday, October 2, 1902.

The Industrial Development of Indigo.

BY J. MERRITT MATTHEWS, PH.D.

The triumphs of chemical research in the fields of industrial life have attained such a height at the present time that the mind of the layman is no longer astonished at any marvel which may be accomplished. It requires a scientific mind and training to appreciate the numerous obstacles which must be overcome in the successful pursuit of an intricate chemical research. The outsider only sees the results in their entirety; the path by which that result was reached, though tortuous, dark and difficult to climb is not apparent except to the technologist.

Somewhat more than thirty years ago, when it was announced that the coloring matter contained in the madder root, and so extensively employed for the dyeing of red colors, had been made in the chemical laboratory from materials extracted from coal-tar, it elicited a great deal of surprise and comment, both from the laity and from men of science; and this surprise was furthermore increased when it was demonstrated that this red coloring matter, which became known as alizarin, could be manufactured not only in small experimental quantities in the chemist's test-tubes, but on a large commercial scale, and at a cost which soon drove the naturally occurring article almost completely from the market. Since then the development of the dye-stuff industry in the manufacture of numerous colors from coal-tar has had such rapid strides that people ceased to be astonished at results which would otherwise have been accounted marvelous; so that a few years ago, when it became known that the highly important coloring matter, indigo, had been successfully made from coal-tar, it only excited a passing mention, and indeed but few people outside of the profession were even aware that such a result

had been accomplished. And yet, the synthetic preparation of this dyestuff was one of the most far-reaching successes that chemical research has won. It was not the result of accidental discovery nor of haphazard experiment, but the outcome of twenty years of patient labor along well-defined lines of scientific development. The successful culmination of this work is a monument to the unwavering and strong-hearted faith of the chemist to the ideals of his science.

A word now as to what indigo really is. To the ordinary individual it stands for a certain blue color which is extensively dyed on all manner of textile materials. The technologist knows it as the most extensively employed dyestuff both of past eras and of the present time. It is derived from the indigo plant botanically known as *Indigofera tinctoria*, which means, "I make things of a blue color." This plant grows extensively in certain provinces of India and in various islands situated in the Indian Ocean, though it has been cultivated with a greater or less degree of success in numerous other localities. The extraction of the dyestuff from the plant is rather a complicated and wasteful process, and depends on fermentation rendering soluble certain ingredients held in the plant which a subsequent oxidation by the air converts into indigo. The dyestuff itself does not appear to exist ready-formed in the plant, but is contained therein in combination with a sugar-like body, the resulting compound being known by the name of *indican*. The plants are harvested at the proper time and the leaves and stems are immersed in water and allowed to macerate until an active fermentation has been engendered. When this process has proceeded to a sufficient degree the turbid greenish steeping liquors are drawn off into shallow tanks usually built of masonry. There the liquor is stirred up and beaten so as to expose it very thoroughly to the action of the air, after which treatment it turns blue, and on standing for some time deposits a blue muddy sediment which is collected, freed from excess of water by means of filter presses, and finally dried and pressed into blocks. This constitutes the natural unrefined indigo which formerly was

so largely brought into trade. It may be said that only from 0.2 to 0.3 per cent. of the weight of the plant is finally obtained as indigo.

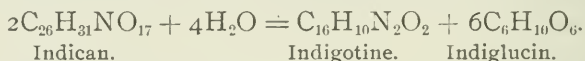
The amount of coloring matter or indigotine in this crude natural product will vary from 10 to 70 per cent., according to the amount of accidental impurities, or the sophistications of unscrupulous dealers. Of late years, however, on account of the stern competition and the demand for greater purity, it has become the custom, to a great extent, to refine the crude indigo by chemical means, so that products can be obtained having as high as 90 to 95 per cent. of indigotine. The cultivation of the indigo plant, however, is a very precarious industry, so much depending upon climatic conditions for the success of the crop, in consequence of which both the quality and quantity of indigo produced were liable to great fluctuations from year to year.

It is a matter of some surprise that though indigo has been such an extensive article of commerce, and of almost universal use throughout the world, very little of scientific value was known concerning its chemical nature and constitution until comparatively recent years. The fact, however, is that its chemical constitution is a very complex one, and required the highest refinement of scientific knowledge to be brought to bear upon it before a clear insight into its molecular structure was attained. For the pursuit and final solution of the problem we are indebted to the indefatigable labors of Adolph von Baeyer, who for more than twenty years worked patiently upon this research, unraveling successfully, one after another, the many complexities with which the problem was surrounded.

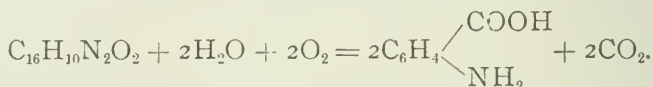
It is historically interesting to know that from the study of indigo really sprung the early beginnings of the coal-tar dyestuff industry. As is well known, Unverdorben, in 1826, first discovered aniline in the products of distillation derived from indigo; and even further back than that, Haussmann, in 1788, prepared picric acid—really the first of the artificial coloring matters—from indigo, by treating the latter with nitric acid. The etymological derivation of the name aniline is also connected in an interesting manner

with that of indigo. The Sanscrit term for indigo is *nila* (signifying dark blue); this was adopted into the Portuguese under the word *anil*, from which in turn is derived the word *aniline*.

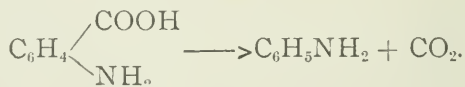
A full discussion of the chemical studies involved in the demonstration of the proper formula for indigo would engender too many complexities to be considered in this paper, and a brief review only of the principal points will be given here. As already mentioned, indigo in the plant exists in the form of a glucoside known as *indican*. This is capable of being hydrolyzed, by the action of dilute acids or of suitable enzymes, into indigotine and a glucose.



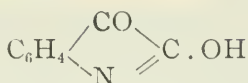
The empirical formula for indigo had been established by Crum and Laurent to be $\text{C}_8\text{H}_5\text{NO}$, and subsequently Sommaruga, by a study of its vapor-density, found that its proper molecular formula should be double that given by the empirical formula, or $\text{C}_{16}\text{H}_{10}\text{N}_2\text{O}_2$. Baeyer took up the investigation of its constitutional formula in 1865, and worked it faithfully to a successful conclusion. He found that indigotine was converted by oxidation in the presence of dilute alkalies into anthranilic acid; in other words:



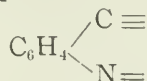
From this reaction it would seem apparent that the indigo molecule contained two phenylene groups, $\text{C}_6\text{H}_4<$, and that the nitrogen atom was probably an amido group or a residue of such. This reaction was also in keeping with the one whereby aniline was obtained by the destructive distillation of indigo with caustic alkalies, since the anthranilic acid, first formed as above indicated, would be further decomposed into aniline:



It was also found that a body known as isatin could be obtained from indigo by oxidation. The structural formula of this body was worked out carefully and found to be:



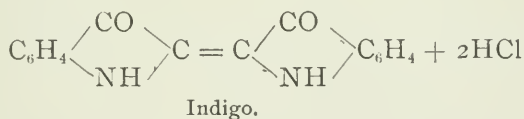
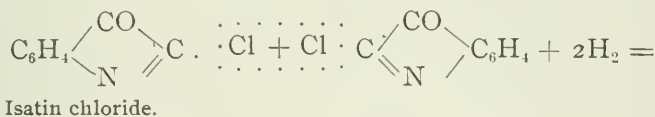
which was additional proof that the indigo molecule probably contained the group



This opinion was still further strengthened when it was found that indol by simple oxidation could be converted into indigo:



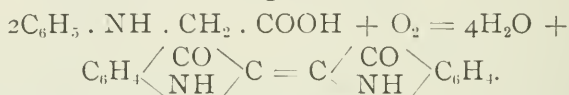
The next step was the discovery that indigo could also be obtained from two molecules of isatin chloride by removing the chlorine, and as the new linking of the atoms of carbon would have to take place at the points occupied by the chlorine atoms, the following equation was reasoned out:



In this manner the above formula was deduced for the proper structure of the indigo molecule, and all its subsequent reactions and methods of derivation have confirmed it as being true.

After its proper structural formula had been worked out, the next step was to prepare indigo synthetically. Its first synthesis had already been attained by Baeyer in the reduction of isatin chloride, as above indicated, but this was of no value from a commercial point of view. Several syntheses of minor importance were soon worked out in the succeeding few years, but they were of only theoretical

interest, and may be passed over with the bare mention that one was from ortho-nitrocinnamic acid (Baeyer, 1880). This was of interest as being the first synthesis to be patented. This body was converted into ortho-nitrophenylpropionic acid, which was used to a certain extent in printing in connection with sodium xanthate for the production of indigo directly on the fiber. The first synthesis of real importance was that discovered by Heumann (1890), who used phenyl-amido-acetic acid (otherwise known as phenyl-glycocoll). It was found that this body, on fusion with caustic potash, yielded indigo—or rather indigo white or reduced indigo was at first produced, which, on oxidation by the air, was speedily converted into indigotine itself:



Although this reaction forms the basis of the present successful methods for preparing synthetic indigo on a commercial scale, yet it was not until it was found that naphthalene could be employed as a raw material from which to make the phenyl-glycocoll, that the process became commercially available. Naphthalene, on treatment with fuming sulphuric acid, is converted into phthalic acid, which by successive stages is converted into phthalimide, anthranilic acid, and then to phenyl-glycocoll ortho-carboxylic acid, from which the indigo is finally prepared by fusion with caustic potash. The successful commercial preparation of these successive bodies was only reached after tedious and thorough research on the part of specially trained chemists. Each step presented certain difficulties which had to be surmounted. A very large amount of fuming sulphuric acid was required, and the cost of this had to be brought down within certain limits. This led to the development of the contact process for the manufacture of highly concentrated acid. The Badische Anilin und Soda Fabrik, by whom this work was chiefly carried out, recover over 40,000 tons (in 1900) of sulphur dioxide formed in the reaction converting naphthalene into phthalic acid, and reconvert it into sulphuric acid by the contact process.

Also, monochloroacetic acid had to be employed for converting the anthranilic acid into the phenyl-glycocoll compound, and it was found that this body was required of a very high degree of purity, which developed a process of making it from liquid purified chlorine and acetic acid, and in order to obtain it sufficiently cheap, the chlorine was prepared by an electrolytic process from salt, instead of the old methods of Deacon and Weldon.

The last few years (since 1897) have witnessed the successful exploitation of synthetic indigo upon the market on a large and continually increasing scale. Its manufacture has evidently proved lucrative, for several large dyestuff firms are engaged in its preparation. Besides the Badische Company, already mentioned, the Farbwerke Höchst are also large producers of indigo. These two firms for a number of years associated themselves in working out the synthesis of indigo, but since its commercial realization they have adopted certain modifications which give them slightly different methods of attaining the same end. The Société Chimique des Usines du Rhone, at Lyons, France, have also entered the field of indigo manufacture. This firm starts from toluene as the raw material and works up through ortho nitrobenzaldehyde to indigo. Other large firms are also bending their efforts to obtain other processes to arrive at the same result. In consequence of all this activity on the part of the dyestuff manufacturers, and in view of the fact that the synthetic indigo is appearing in such large quantities on the market, and at a price which can undersell the natural product, we may soon look forward to the eventual total extinction of the natural indigo industry, in the same manner as the madder-root industry was quickly obliterated by the production of synthetic alizarin. Synthetic indigo appears to have all the essential qualities of the natural dyestuff, and can be prepared in a much purer state, so if anything it is really somewhat better in its quality than the natural product. And thus is recorded another triumph of chemistry over the clumsier processes of nature—and withal, that the very science which surpasses nature is but a science that nature makes!

A GREAT ENGINEERING FEAT COMPLETED.

With the laying, on the first day of the present month, of the last coping stone of the great dam across the River Nile at Assouan, the ancient land of the Pharaohs sees the completion of a national work, which is not only the greatest of its kind in existence, but in its beneficent results will probably outrank any scheme carried out in Egypt, either in ancient or modern times. The completion of this dam and a similar structure at Assouan will provide in the Nile Valley a vast reservoir capable of supplying over 1,000,000,000 cubic yards of water every year. The surplus waters of the river will be stored during the flood season, and then drawn upon for the irrigation of wide tracts of land which for many centuries past have lain waste for want of water. As a result of the new system of irrigation, there are extensive tracts of land which henceforth will bear two crops a year where formerly they bore but one; while the area devoted to sugar cultivation will be greatly increased. The Assouan dam itself is one of the greatest engineering works in existence. It is no less than $1\frac{1}{4}$ miles in length and it is pierced by 180 sluice-gates 25 feet in height and 7 feet in width, by means of which the regulation of the waters will be secured. The total cost of the two dams will be about \$25,000,000, and the work has already proved itself to be an important economic feature in the life of the Egyptian people, for no less than 14,000 natives have found continuous employment during the progress of the work. The inauguration and rapid development of this great scheme has been due entirely to the enterprise of a Western race, entirely alien to the Egyptian people; and there is something peculiarly fitting in the fact that Egypt, which contributed so largely in its earlier days to the world's arts and sciences, should in these later times be thus richly endowed by the highly developed engineering skill of our modern civilization—*Scientific American*.

ALCOHOL MOTORS IN GERMANY.

The alcohol or "spirit" motor industry has been developing very rapidly in Germany. The chief advantage of these motors as compared with steam-engines are that they are always ready for work without a preliminary warming up; they can be filled up, oiled and started in from two to three minutes, there is no constant supplying of coal and water, no danger of fire or explosion, no consents required from Government authorities and no compulsory inspection. Their working is independent of the state of the weather, the "spirit" is easily obtainable in all districts, there is no smoke or smell, and the weight of portable "spirit" motors is about half the weight of portable steam-engines of equal power. The "spirit" for motors, containing 90 per cent. of pure alcohol, can be purchased at from 20 pfennige to 22 pfennige per liter (about 3 cents per pint), delivered at any station in Germany. The motors exhibited at an agricultural fair at Halle last year were from 1 to 25 horse-power. As regards cost, the Dürr Motor Company were exhibiting portable spirit motors of 6 to 8 horse-power at \$1,000, 10 to 12 horse-power motors at \$1,300 and 16 to 20 horse-power at \$1,625. Of the tests made one trial gave a consumption of 0.92 pound of 86 per cent. spirit and 0.81 pound of a mixture of $\frac{1}{2}$ benzol and $\frac{1}{2}$ 86 per cent. spirit, in both cases per B.H.P. per hour.—*Iron Age*.

Mining and Metallurgical Section.

Stated Meeting, held January 8, 1902.

The Anthracite of the Third Hill Mountain, West Virginia.

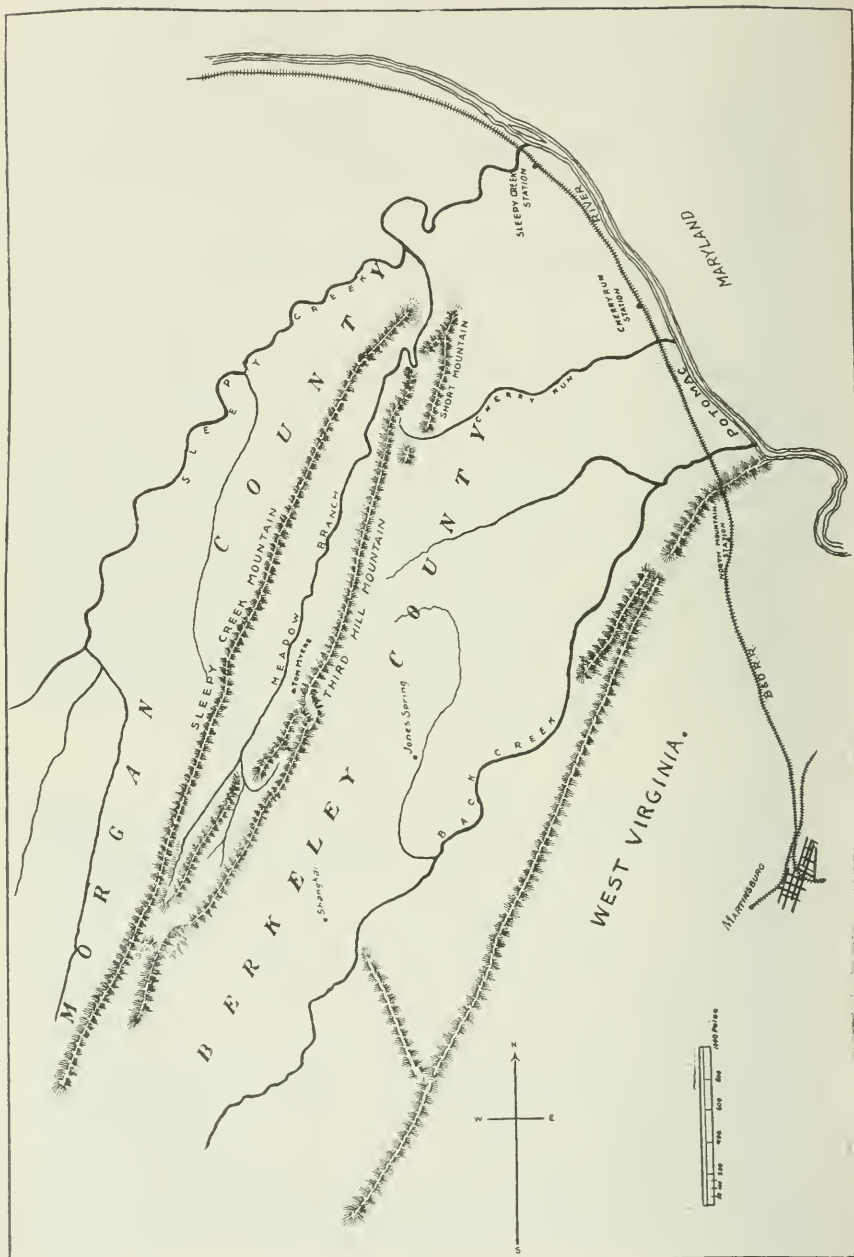
BY WILLIAM GRIFFITH, Mining Engineer.

SITUATION.

The Third Hill and Sleepy Creek Mountains are located in Berkley and Morgan Counties, West Virginia. They extend nearly north and south (N. 25° E.), the northerly end being about 13 miles west of Martinsburg, 7 miles east of Berkley Springs. Sleepy Creek Station, on the Baltimore and Ohio Railroad, is the nearest point by rail, being three or four miles north of the northerly end of the mountains, while Cherry Run Station (the junction point of B. & O. R. R. and Western Maryland R. R.) is 6 miles distant. This station is 124 miles by rail from Baltimore, 84 miles from Washington, 68 miles from Cumberland, 18 miles from Hagerstown and about 200 miles from Pittsburg.

TOPOGRAPHY.

As before stated, these mountains extend southward from near the Potomac River, having general direction of about S. 25° W. and are nearly parallel, being separated by the valley of Meadow Branch, which rises near the southerly end of the valley on the slope of Middle Ridge (a hill which gradually rises from the center of the valley, and increasing in height southward unites the two mountains). From Middle Ridge the Meadow Branch flows northward and empties into Sleepy Creek, a stream of considerable size, which drains the valley lying west of Sleepy Creek Mountain. The Back Creek Valley to the east of Third Hill is drained by Back Creek and its tributaries, and flows also into the Potomac west of Martinsburg. A good idea of the relative positions of these mountains can be obtained



from the sketch map by noting that their general outline somewhat resembles a fish, Sleepy Creek Mountain forming the back, Third Hill the belly, and Middle Ridge uniting the two at base of the tail. Their southern extension, including Brush Creek Valley, forms the tail, while the nose and mouth are formed by the north end of Sleepy Creek Mountain and Short Mountain, the latter being a detached portion of the north end of Third Hill.

The crests of Third Hill and Sleepy Mountain are about 1,000 feet above the general level of Sleepy Creek and Back Creek Valleys and about 500 feet above Meadow Branch Valley, which latter, at Tom Meyer's, 11 or 12 miles south of the B. & O. R. R., is 600 feet higher than Sleepy Creek Station.

The coal beds, which are the especial object of this paper, are found in the rocks which flank the east side of Third Hill. At the southerly end, *i.e.*, near the fish's tail, the outcrops are near the crest of the mountain; but to the north the rocks containing them gradually separate from the main hill, forming Short Mountain, above mentioned. The space between Short Mountain and the main ridge is occupied by soft red shales, forming a sort of valley, in which several mountain streams have their source, which have cut channels or passes through Short Mountain, thus dividing it into a chain of short ridges lying end to end, parallel to Third Hill proper, and as the crests of these ridges are formed by the hard and almost vertical strata in which the coal is found, it will be seen that the coal outcrop runs lengthwise of the highest crest of Short Mountain and across the passes through which the Cherry Run and other brooks flow, as above mentioned, and that the coal beds are very accessible by water-level drifts lengthwise of the vein from the creek beds.

GEOLOGY.

A knowledge of the geology of this region is of the utmost importance in determining the value of the Anthracite coal in Third Hill; for if we know positively their geological position, we have gone a long way toward

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determining their economical value. The following ideal cross section will serve to illustrate:

In the first place, we find that both Sleepy Creek and Back Creek Valleys are occupied by the soft red and yellow shales and black slates of the middle and upper Devonian measures, the lowest rocks of the series being in each valley farthest from the mountains in question, while the highest rocks of the Devonian Age (the red shales of the Catskill group, or No. IX of Pennsylvania Geological Survey), are found flanking the west slope of Sleepy Creek Mountain and the east slope of Third Hill. The crest of both of these mountains is formed by a ridge or spine of hard white and gray sandstone, being the lowest rocks of the sub-carboniferous or Pocono measures, and these same rocks form the mountain-sides sloping down to Meadow Branch.

The rocks in the crest and in the east flank of Third Hill and the Black Creek Valley are overturned or inverted, as shown by their decided dip to the east, while in Sleepy Creek Mountain and Valley the rocks are regular and dip also to the east. Thus we see that the two mountains are formed by a long, narrow, canoe-shaped trough or basin of hard Pocono sandstone, resting upon the soft red rocks of the valley. And it is through this basin that Meadow Branch flows, breaking its way through a precipitous gorge at the northerly end.

Now, while there are coal openings on the west side of Meadow Branch in a number of places, those in Third Hill are particularly interesting in this paper, and we will confine ourselves to the developments along its crest.

Anthracite coal has long been known to exist in Third Hill, and in fact has been found far to the southward and also to the northward in the same general range of Pocono rocks at various places. At Third Hill, however, more than any other one locality, the coal has been proved by many test-pits dug into the outcrop along the crest of the mountain for 12 or 15 miles, and while these provings have been very alluring to prospectors, and considerable time and money has been spent, both in shafting and boring with

diamond drills, as yet no coal beds have been found of sufficient value to warrant the expense necessary for their development. The true carboniferous formation, which includes the productive coal measures of Pennsylvania and West Virginia, are much higher in the geological series of rocks than the Pocono (in which the coal in question is found). And in Pennsylvania no Anthracite coal of workable thickness has ever been found in the Pocono rocks. It is true that in a few localities, notably in Kentucky and Tennessee, and in one or two special points in Pennsylvania, bituminous coal is mined in the low or carboniferous measures. At the same time, these beds are not so regular as to thickness and are more subject to faults and disturbances, and, consequently, are more costly to mine than beds of the true carboniferous age. As a rule, when bituminous coal exists, the measures are not much disturbed or distorted, and the coal lies flat or on moderate dips, very much as originally deposited; while in the case of Anthracite coal, the conditions are quite different, as it only occurs in highly disturbed measures, where the coal (originally supposed to have been bituminous) has been coked or distilled under the heat and great pressure, due to the distortion of the rock formation in which it exists. The Anthracite beds of Pennsylvania are therefore found to contain more slaty refuse and are more subject to faulty squeezes, crushed coal, etc., than the bituminous beds of the same age. Again, the Pocono rocks are known to be false-bedded and much more irregular in their stratification and more liable to faults, crushes and other irregularities, than the rocks of the true coal measures.

As a result of the above facts and the known geological position of the beds of Third Hill, in connection with their steep dips (usually inverted) and the evident distortion and folding of the measures, we must expect to find the coal beds more or less crushed throughout the region, and in much the same state as the crushed and faulty coal of the Pennsylvania Anthracite beds. In addition to this, the beds would probably be found more irregular and erratic as to thickness and continuity, existing more or less as "pockets,"

and very uncertain as a basis upon which to make a large investment of capital necessary to development for railroad shipment.

The provings noted on Third Hill were made many years ago, the most recent provings west of Shanghi and near the source of Cherry Run, and it was impossible to get fresh samples of coal from the seam for analysis or tests. It is reported that a number of wagon-loads of coal were hauled away from the various shafts and sold, and found to give very good satisfaction as fuel, and apparently equal to Pennsylvania Anthracite. Analyses of fresh coal have been shown me, which average about as follows:

Volatile matter	about 10 per cent.
Fixed carbon	84 " "
Ash	6 " "

From this we should take the coal to be a semi-Anthracite, free-burning, white ash, approaching in quality the coals of Shamokin and Bernice, Pa., which are classed as Anthracites. It is probable that the above analysis is from picked samples of pure coal, and that the average of the vein would show much higher percentage of ash, owing to the bony coal and slate which would remain intermingled with it, even after careful preparation. The coal does not yield readily to the influence of the atmosphere, as is shown by the good condition of coal exposed ten or fifteen years at the proving shafts.

The rocks of the mountain in the south end, where the recent Shanghi provings were made, are much disturbed, and the coal bed in the proving shaft is inverted and the coal badly crushed.

At this point a distinct basin is found in the hard Pocono rocks near the crest of the mountain. This basin is about 500 feet wide, and shallow. The proving shaft was about 8 feet square, 50 or 60 feet deep, and sunk in the coal outcrop on the east margin of the basin. The writer was lowered into the shaft by means of a bucket and rope attached to the hoisting engine, and found the coal bed—which was supposed to be about 10 feet thick—much

crushed and faulty, as has before been mentioned, and practically worthless. Near the bottom of the shaft the bed seemed to be parted by layers of fire-clay or slate, and in worse condition than at the top. This shaft was shortly afterwards abandoned.

On the western outcrop of this narrow basin the rocks were regular, dipping to the east about 40° . A short tunnel had been driven westward into the hill, cutting a bed of coal about $2\frac{1}{2}$ feet thick. The writer examined this vein, after having the tunnel cleaned out, and found that though the dip was regular and bed right side up, the coal was in much the same condition as in the shaft; and that while a small quantity had evidently been mined out and used locally by the farmers in the valley, the bed was virtually valueless for general development.

Previous to sinking the shaft above mentioned, much money had been spent in driving a tunnel horizontally into the east flank mountain, about half-way down, all the way through red rocks of No. IX, in hopes of cutting the vertical coal bed 200 or 300 feet below the surface. The tunnel (about 7×8 feet) was driven several hundred feet into the mountain, and at its end diamond-drill holes were bored horizontally 100 feet or more, until the water-pressure forced the drills out and stopped the future progress of the work. This tunnel would not cut the coal if it had been extended clear through the mountain, as it was probably far below the bottom of the shallow basin containing the bed. A diamond-drill hole had also been bored in top of the mountain, but outside of the coal basin.

As noticed above, as we go north from the Shanghi provings, the ridge containing the eastern coal outcrop gradually separates from the main ridge, and if the same basin-structure is maintained it becomes wider and deeper, allowing an area of red shale between Short Mountain and the main range, as priorly noted, and permitting the coal to cut down as low as the bottom of the lowest creek beds in the foothills near the valley. At the provings north of Shanghi the rocks seemed to be more regular, in some places vertical or with slight westerly dip, and not being inverted, owing

perhaps to their being higher and nearer to the summit of the overturn. The coal, except on the dumps, which had been taken from the shaftings, showed slightly better fracture, though much crushed and faulted. Further to the northward, in the vicinity of the lands near the head of Cherry Run, about the same conditions are found, the strata dipping about 80° to the eastward and inverted. The outcrop has recently been cut by a drift on the north side of Cherry Run Gap of Short Mountain, and more recently at a shaft in the gap southwest of Norrington's peach orchard. This shaft is about 5×8 feet, and it is said to be over 50 feet deep. Coal was struck about half-way down, and it is said to be about 4 or 5 feet thick. A number of tons were sold to the farmers nearby for upwards of \$4 per ton, and was pronounced of satisfactory quality. Although this shaft was filled with water—and we were not permitted to examine the coal in places—we were able to judge of its structure and condition by the heap of coal, dirt, etc., still piled near the top of the shaft. It is unquestionably in the same crushed and faulted condition as found at every other point in the region where openings have been made.

As to the thickness and general condition of the coal in the beds north of Shanghi I cannot say, except from inference, as all the openings were long since filled. We noticed, however, that the pieces of slate exposed on the dumps had not the flat, laminated structure of the interstratified slate of the Pennsylvania Anthracite beds, but had the same shape and crushed appearance that characterized the coal, and was hard to distinguish from the coal, except by its greater weight or by breaking. This fact is an indication of the crushed, faulty condition of the beds, and of the great pressure to which they must have been subjected, as it is evident that the pressure was sufficient to crush not only the coal but the slate also, and force it out of its true stratified condition. The slate carries considerable iron and is much heavier than coal. Owing to this fact, it could be readily separated from the coal by the process of jigging common in Pennsylvania Anthracite regions. The writer had a proving-hole dug into the outcrop of a bed of coal in

Meadow Branch Valley, west of Tom Meyer's house, and found a $3\frac{1}{2}$ to 4-feet thickness, lying in good position between regular dipping rocks, but the coal was of the same crushed and slippery character referred to above; and while the coal would probably burn good, the crushed condition would cause an excessively large percentage of fine coal, such as pea, buckwheat, and dust, which would much reduce the market value of the product, as would also its soft and friable nature; on account of which it could not stand much handling, but would readily crumble, causing much fine culm and waste.

Our investigations of this curious coal field have led us to regard the coal beds of Third Hill as a sort of natural curiosity or geological freak, and, owing to uncertainty as to thickness and continuity, and probable unreliable or "pockety" and faulty nature of the beds, their economical value is small. There can be no doubt that the above-described crushed condition of the coal beds extends throughout the region, including the deeper parts of the seam, far below the surface, as well as near the outcrop. Of course, if the coal beds in Third Hill were proved to be 3 or 4 feet thick or more, continuous and reliable, the large investment required to develop for railroad shipment would be justifiable, notwithstanding the crushed condition of the coal, for the location, excellent railroad facilities, and good market, at high prices, would go a long way toward counterbalancing the loss due to poor fracture or faulty coal. But to attempt to prove the reliability of these seams as to thickness, continuity, etc., would require a considerable expenditure, which would, in the writer's opinion, be very likely to result unfavorably.

SULPHURIC ACID BY ELECTROLYSIS.

Mr. Clinton Paul Townsend, in the *Electrical World and Engineer*, says: "Faraday and a host of subsequent experimenters have investigated the electrolytic oxidation of sulphur dioxide in aqueous solution, and have found that under normal conditions one-half the oxide undergoes oxidation to sulphuric acid at the anode, the remainder appearing as sulphur or sulphureted hydro-

gen at the cathode. In 1895, however, Dr. Leonard Wacker succeeded in rendering the oxidation quantitative by the concurrent use or production of carriers of oxygen, such as the persulphates, or even the halogens. Mr. Charles B. Jacobs now finds that the same result may be accomplished by a judicious application of the principle that oxidation is facilitated by a concentrated solution and low current density at the anode. In Jacobs' apparatus the anode is a porous composition through which the gas is injected in a continuous stream into the cell; and the anode area is thirty-three times that of the cathode. In the apparatus used the vessel is provided with horizontal electrodes and an interposed diaphragm. The porous anode constitutes a partition near the base of the cell, and into the lower compartment so formed sulphur dioxide is injected through the pipe, passing through the previous anode and undergoing oxidation therein. An outlet is provided for withdrawal of the sulphuric acid when the hydrometer shall indicate that the desired density has been reached. A refrigerating jacket is provided in order that advantage may be taken of the increased solubility of sulphur dioxide at 0° C.

"Jacobs, like Wacker, finds that by continuously injecting sulphur dioxide the sulphuric acid may be brought to standard concentration. While, as stated, the reaction, chemically considered, is quantitative, all of the sulphur dioxide being converted, the electrolytic efficiency is given as 54 per cent.; this result is attained with a potential difference of two volts and a current density of 15 to 20 amperes per square foot of anode surface."

THE METRIC SYSTEM.

One of the most interesting and important steps taken by the Colonial Conference that has just been sitting in London is the adoption of a resolution in favor of the metric system for all the British Colonies. Perhaps too much weight may be attached to this expression of opinion, but the Colonial statesmen met strictly for business, and would certainly not approve of such a change or policy unless they knew that it was in harmony with the sentiments of their people, whether in Canada, at the Cape, or away off in Australia and New Zealand. We are inclined ourselves to derive encouragement from this formal utterance, and to believe that in a short time necessary steps will be taken to give it force, wherever the state of the law so requires. The progressiveness of the British Colonies is a familiar social phenomenon, and their approval of the metric system will do much to assist in molding opinion and action in the United Kingdom, as it has already done in other matters. The benefit to international intercourse cannot be overestimated, and we may be sure that the Colonial officials did not go on record without adducing weighty arguments of that nature in support of their resolution. We are not aware what process exists for giving force and validity to these verdicts and decisions reached by the statesmen of Great Britain, but it is safe to infer that practical leaders of Colonial politics do not meet merely to pass resolutions. Their function is indeed growing rapidly into one of vast significance and utility, and it was never exerted to more beneficial unifying effect than in helping to create throughout the wide dominion of King Edward a simple, universal system of weights and measures.—*Electrical World*.

Section of Photography and Microscopy.

Stated Meeting, held Thursday, October 23, 1902.

A New Binocular Microscope.

BY FREDERIC E. IVES.

It was once believed by a great many microscopists that the merits of the binocular microscope were such that it had "come to stay," and would grow steadily in popularity. On the contrary, it has come into such disrepute that several leading microscope manufacturers no longer even list binocular microscopes, and dealers who had them in stock have been closing them out at less than cost of manufacture.

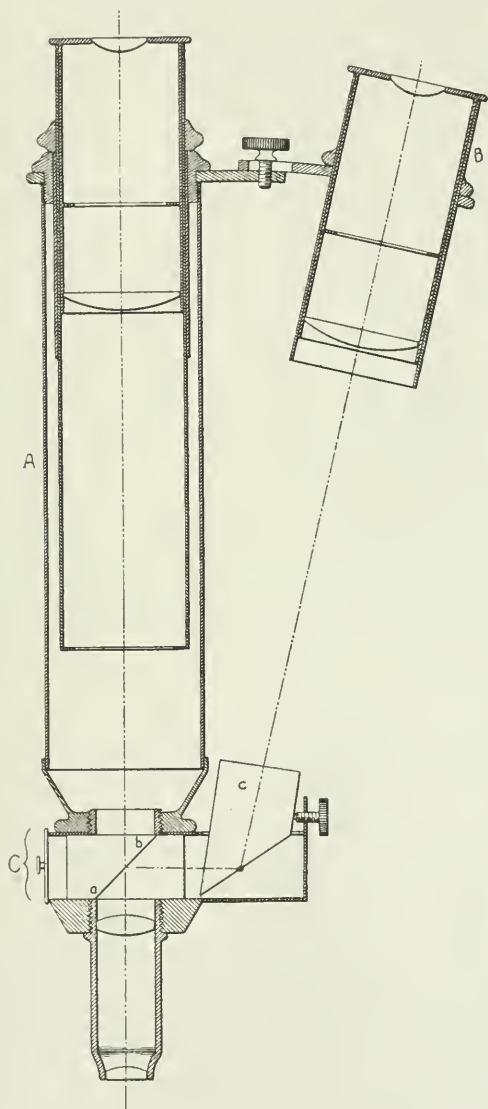
There are several reasons for this state of affairs, among which may be mentioned the following: (1) The Wenham, Nachet and Riddell binoculars all divide the light by prisms at the backs of the objective, with the result that the diffraction pencils which should define the most minute details of the right-eye image go to the left eye, and *vice versa*, so that neither image is sufficiently perfect when large aperture objectives are employed. (2) All binocular microscopes have long tubes, whereas most of the high-power objectives are now made to give their best results only with the short or "Continental" length of tube. (3) Owing to the unnecessary length of the mounts of most of the medium-power objectives, and the common use of revolving nosepieces, the position of the binocular prism is so far above the back lens of the objective that the best results are seldom obtained, even in the use of those powers with which the Wenham binocular is capable of giving satisfactory images. (4) Even those who would prefer to use the Wenham binocular for low powers cannot well do so except by having two microscopes, because it is important to have one with variable tube length.

It is evident, that in order to popularize the binocular microscope, it must first be freed from the defects which I have enumerated.

Some months ago I devised and constructed, and have since been using with considerable satisfaction, a binocular microscope which possesses the following advantages: (1) It is a "short-tube" microscope. (2) The parts which make it a binocular may be attached to an ordinary microscope without alteration. (3) It is not an expensive attachment. (4) It does not interfere with the use of the microscope as a monocular, with variable tube length. (5) It may be used either as a binocular non-stereoscopic microscope, or as a binocular stereoscopic microscope. (6) As a non-stereoscopic binocular, it sends to both eyes images practically identical with the single image of a monocular, no diffraction pencils being cut off from either image, and is as satisfactory with the highest as with the lowest powers, dividing the work evenly between the two eyes even when doing the most critical work. (7) As a stereoscopic binocular, it yields to both eyes images distinctly more perfect than either image in a Wenham binocular, and while giving true stereoscopic relief with medium and low powers, never exaggerates this effect, as the Wenham binocular sometimes does. As against these advantages may be placed the fact that it requires a little more skill to adjust it than the Wenham binocular; but it should not be at all troublesome to the expert microscopist.

The two attachments which effect this change in an ordinary microscope are, (1) a small prism box with set screw to fit the lower end of the microscope tube, and (2) an attachment to the upper end of the tube to carry the second eyepiece, with means for adjusting to suit different pupillary distances. The complete outfit is shown in *Fig. 1*, in which *A* is the microscope tube, *B* is the extra eyepiece and fitting, and *C* is the prism box. The prism box contains one compound cemented prism with transparent silvering on one of the inner faces, *a*, *b*, and a single prism, *c*. The dotted lines show the path of the axial ray, half of which is transmitted through the compound prism and the other half reflected into the prism *c*, and thence to the auxiliary eyepiece. The body of the prism *c* is extended in the direction of the eyepiece for the purpose of making the

optical length of both axial rays alike, so that matched eyepieces may be used; otherwise, the auxiliary eyepiece must



be a little longer in focus than the one in the main tube. Two adjustments are required—first, an adjustment of the auxiliary eyepiece to suit the pupillary distance, and then

an adjustment of the prism c to center the respective image, so that it corresponds to the image seen in the other eyepiece. It would evidently be possible to connect these parts and provide a differential movement, so that only one adjustment would be required; but the simplicity of the present arrangement commends it.

There are three ways of changing from binocular non-stereoscopic vision to stereoscopic vision. The first consists in covering a portion of the top of the compound prism, so that the image sent to one eye corresponds to the image that would be sent to that eye by a Wenham binocular. This may be effected with a little metal slide which can be pushed to a stop when required in an instant. This method of securing stereoscopic effect works best with short-mount objectives, and is then more satisfactory than the Wenham, because, although the stereoscopic effect is quite positive with low and medium powers, one of the images is made by the whole of the objective, and is therefore better than either of the images in the Wenham, the slight loss of light from reflecting surfaces not affecting the quality of the definition. This, however, is not the method which I prefer. The other two methods depend upon the fact that decentering the eyepoints is equivalent to covering opposite sides of the back of the objective, from which it follows that bringing the eyepoints a little closer together than the pupillary distance of the observer secures stereoscopic vision, and separating them to more than the pupillary distance secures pseudoscopic vision. The necessary amount of decentering does not amount to an eighth of an inch, does not cut off any of the field to either eye, and yields better definition than is possible with the Wenham, because the central group of rays goes to both eyes alike. This change of adjustment is readily made, but it is an interesting and, to my mind an important fact, that the change from stereoscopic to non-stereoscopic and to pseudoscopic vision can be made in the most perfect manner by the much simpler expedient of holding the eyes within or without the plane of the eyepoints. Owing to parallax of axes, if the adjustment corresponds exactly to the pupillary distance at the plane of

the eyepoints, the axial rays will be less separated below the plane of the eyepoints and more separated above that plane; and this is so far true, that with low-power objectives and 2-inch eyepieces one may have either stereoscopic or non-stereoscopic or pseudoscopic vision without moving the eyes to and from the eyepieces enough to cut off any of the field of view. I prefer to set the instrument for my own eyes so that exactly at the plane of the eyepoints vision is feebly stereoscopic; below that point, fully stereoscopic, and just above that point, non-stereoscopic; pseudoscopic vision may still be obtained by withdrawing the eyes until the field of view is somewhat cut down, and the objects may therefore be presented to the eyes in three distinct and informing aspects by changes almost as quick as thought. With high-power objectives, the entire field is seen perfectly only when the instrument is adjusted for non-stereoscopic vision with the eyes in the plane of the eyepoints.

A discussion of the practical value and importance of such protean characteristics in a microscope would doubtless disclose very diverse opinions, and while calling attention to their novel and interesting character, I must leave it to the future to decide whether such an instrument fills a real want.

THE USE OF PETROLEUM IN MAKING PIG-IRON.

Two Russian engineers, named Pitsky and Ivanoff, have devised a process by which petroleum can be utilized in the production of pig-iron in connection with a certain quantity of solid fuel. In a paper read before the Baku Technical Society, the following description of the process was given :

The solid fuel is placed in a special generator, into the lower part of which are introduced the heated gases from the combustion of petroleum. The fuel charged from above gradually falls to the bottom and becomes heated ; dry distillation results, and the gaseous products are drawn off from the upper part of the generator and utilized for fuel, while the resulting coke continues to descend. The products of combustion entering the lower part of the generator pass over the incandescent coke, are deoxidized, and are thus available as reducing agents, which can afterward be used in the second furnace. This furnace, which is used for producing iron, resembles an ordinary blast-furnace, from which it merely differs in having a tube running down the center. The ore and fluxes are placed in the circular space between the walls of the furnace and the central tube, the latter being charged with a quantity

of coal sufficient to supply the iron with the required equivalent of carbon for converting it into pig-iron, also, if necessary, with fluxes for changing the composition of the slags. The circular space and the central tube are provided with covers to retain the gases. The heated reducing gases from furnace No. 1 are made to enter the lower part of furnace No. 2 through several openings. The gases at first melt the ore and slag. In ascending without changing their composition they convey their heat to the materials, and they begin to act chemically, by reducing the iron oxides, absorbing their oxygen, and becoming converted into carbonic acid. Although the gaseous medium gradually acquires pronounced acid properties, the effect of the carbonic acid is counteracted by the fall in the temperature. The spent gases collecting in the upper part of the furnace are utilized as fuel, the reduction process being preferably carried out by means of carbonic oxide. The central tube terminates at the place where a temperature of 900° C. prevails. The atmospheric medium at this horizon being of a reduced nature, the carbon dropping into the charge could only be utilized in combining with the iron to form pig-iron. The pig-iron and slags produced are tapped in the usual manner. The molten pig-iron from furnace No. 2 is run into the Bessemer converter. The pig-iron is converted into steel; the gases are led into generator No. 1 and serve for producing pig-iron in furnace No. 2.—*Iron Age*.

A NEW MOLDING PROCESS.

The steel-casting industry, which has made such wonderful strides in this country within the past decade, may be said to be still in its infancy, bright minds in the trade continuing to evolve new and still more wonderful ideas. One who has contributed in no small degree to this advancement is Frederick Baldt, Sr, general manager of the Penn Steel Casting Works, Chester, Pa. Mr. Baldt has discovered many new and important processes that have raised the standard of steel casting to a high point, but that he has not been content to rest upon these laurels won in the past is demonstrated by recent achievements. For months he has been engaged in developing ideas that have resulted in the introduction of a system of steel molding that promises to revolutionize the process.

Patents were recently issued to him that will materially simplify the molding of steel. The method consists in first making a master-mold from any pattern and then casting from this as many fusible patterns as may be required. This fusible pattern is then put into an iron box of suitable size, after which, by means of compressed air, the box is filled with molding-sand. The box is then run into the drying oven, where the fusible pattern is melted out. The casting is then made from the dried mold.

An important feature of this process is that it does away with skilled labor, the sand being conducted and driven by compressed air into all parts of the box and fusible pattern by either boys or laboring men. Since the castings are absolutely seamless and without fins, no chipping is required afterward. The process is also particularly applicable to the casting of chains and similar interlocked articles. By this process it is also practicable to produce articles in exact duplicate and in any number.—*Iron Age*.

The "Series-Vapor" and "Heat-Waste" Engines, as Supplementary to Single-Vapor Engines.

BY R. H. THURSTON,
Honorary Member of the Institute.

(*Concluded from p. 390.*)

Mr. Yarrow seems inclined to attribute the certainly great gain by use of the petroleum spirit to its small "latent" heat; but it is certain, as has been seen, that this is not the reason. It would seem much more probable that it is due to a more obvious difference in the physical properties of the fluids compared. In very small steam-engines, such as these, it is well known that the "cylinder-condensation" is enormously large and often amounts to several times the quantity of steam which would be demanded were this form of waste extinguished. Petroleum is a comparatively oily fluid and a most excellent non-conductor of heat; it is one of the best if not the only practically available insulator for high-tension transformers for the alternating electric current. Mr. Yarrow's experiences confirm the deduction, derived from many other sources and experimental investigations, that the extraordinary differences here referred to, which seem to be the greater, as the engines employed are smaller, are due to differences among these fluids in their capacity for producing, or for permitting, heat-exchanges between the working fluid and the inclosing cylinder-walls. Further direct investigation is required to settle this question; but all that can be gathered at present regarding the action of such fluids would seem to harmonize with that method of accounting for an undoubted superiority.

If this deduction is correct, it at once follows that such superiority will diminish as the size of engine increases and as this internal waste of the steam-engine thus diminishes. It is also the fact that, as superheating or other expedient

quenches this waste, the advantage of the more volatile and slowly conducting fluid must become less and may practically disappear. In any event, the work of Messrs. Haswell, Barrus, Magovern and Yarrow and others would seem to have established the existence of such differences as are here referred to, and that beyond question. Their deductions have been hesitatingly published and hesitatingly received by the profession; but this hesitation undoubtedly will be replaced by entire confidence, in the light of such facts as are here collated; while the deductions of Rankine and his followers, from purely thermodynamic considerations, must in that case fail, where the qualifying circumstances of actual work and of real heat-engine operation are taken into account.

Yet there still remain the two questions to be settled, and only by properly prolonged experience: (1) Whether these volatile fluids can on the whole, through their extra-thermodynamic properties, supersede steam as working fluid in even the smallest of simple engines? (2) Whether the "heat-waste-engine," with its volatile secondary fluid, is commercially a success?

The work of Professor Josse is the first of which we have record in which the modern requirements of scientific and complete thermal and dynamic, as well as thermodynamic, energy-transfers and transformations were completely exhibited, and such exact and full data secured as would permit the solution of the long-standing problem of efficiency to be positively and satisfactorily settled for the case studied. It was long ago fully demonstrated that the quantity of work derivable from the waste-heat of the steam-engine, through use of a secondary vapor of relatively high pressure, and thus capable of thermodynamic utilization of waste-heat of the primary machine, was sufficient to justify considerable additional expense in its production. The question was to this extent settled, and the remaining question is that of permanence, of utility, of safety and of ultimate financial gain when the life of the plant and its incidental and direct costs are taken into the account; for the so-called incidental costs of maintenance, replacement, accident and

repair are, in cases such as this, essentially important data which usually long remain undetermined.

The design, construction and adjustments of the binary engine employed in the case in hand were due to expert and scientific minds, and the immediate result of the first tests was the assurance that the gain in power by utilization of the ordinarily wasted heat of even a triple expansion steam-engine of good construction was sufficient to compel attention and probably to justify complete investigation. The outcome of the first series of trials was published at the centennial celebration of the Berlin Royal Technical High-School, Report No. II, 1899. The engine was of 60 to 70 horse-power, and it is reported to be, at last accounts, still satisfactorily in operation. A second engine of 175 horse-power was set in operation, May, 1901, which has given even better results, confirming the impressions made upon the expert investigators by the first machine.

The German experiments have been made with a binary-vapor system in which sulphur dioxide is the secondary fluid. This substance, commonly known as sulphurous acid, has been used to some extent in refrigerating machinery, though not nearly to the extent to which ammonia has been employed. Its properties are well known, and the needed physical data are established with ample accuracy for the purposes of the engineer.

Sulphur dioxide, at a temperature of 140° F., that chosen in many cases as on the whole satisfactory at the point of contact of the primary and secondary systems, exerts a pressure of 156.6 pounds per square inch, and at the average temperature of the cooling water employed in the steam-engine, about 60° F., 40.8 pounds. It rises to 50 per cent-higher figures, with 20° higher temperature, than of hydrant water in warm climates. Its pressures are something more than one-half that for ammonia at the same temperature. The relation of pressures and temperatures of the two fluids are exhibited in the accompanying diagram. (*Fig. 6.*)

This fluid is seriously obnoxious when leaking into the air and it is essential that, as with ammonia, every precaution should be taken to insure absolute tightness in every

vessel into which it is to pass. It is liable, when mingled with air and moisture, to take up oxygen, and to thus become injurious to the metal surfaces enclosing it, although quite free from this objection so long as pure and dry. On the other hand, it is oily in its nature and a good lubricant, and no oil or grease is needed to reduce the friction of rubbing surfaces in its presence. Another probably important and valuable property which it possesses, in common with some other available secondary fluids, is comparatively small susceptibility to the form of waste, "cylinder condensation," often very serious with steam.

Pressure curves of SO_2 vapors.

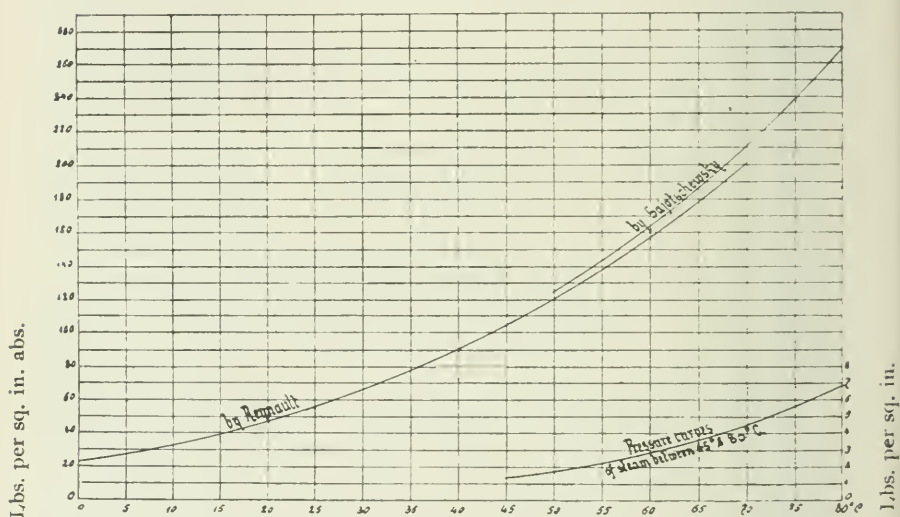


FIG. 6.—Steam and SO_2 .

The Experimental Engine of the Berlin school is a triple-expansion machine, having a rated brake-power of 150 I. H. P. and a normal speed of about 150 revolutions per minute. Its cylinders are of, respectively, 270, 430, 675 mm. diameter and of 500 mm. stroke of piston ($10\frac{3}{4}$, $16\frac{5}{16}$, $26\frac{9}{16}$, and $19\frac{11}{16}$ inches). To this engine was attached the secondary system, a "cold-vapor engine," whose cylinder was of equal stroke and its diameter 266 mm. ($10\frac{1}{2}$ inches).

The details of construction were modified from those of the steam-engine, usually for the purpose of securing more perfect packing of rod and valve-stems, and the latter were made to rotate, rather than given a motion in the axial line, to better insure against leakage. The materials of construction are those usual with the steam-engine. The supplementary cylinder is designed for a maximum working pressure of 215 pounds per square inch. The piston-rod stuffing-box was especially designed to permit the use of grease as a lubricant and yet to avoid its working into the cylinder and through that into the condenser. No lubricant is required for the cylinder, the SO_2 sufficing. "Cylinder-condensation" occurred to such slight extent as to be quite unnoticeable, even at starting.

The "vaporizer" and the "condenser," introduced with the cold-vapor engine, are built, respectively, for pressures of 285 and 115 pounds, and contain 753 and 1,720 square feet of cooling surface. A safety-valve on the vaporizer leads the discharge to the condenser, and the safety-valve of the latter discharges into the open air. It is expected, however, to open very rarely. It was found that the vaporizer is capable of transmitting heat between the two fluids in contact with it about four times as fast, per unit of surface, than does the condenser; while the latter is so well designed as to transmit heat twice as rapidly as is usual in refrigerating apparatus in Europe. The proportions adopted were found to be more than liberal, and it will probably prove wise, as a matter of finance, to reduce them in later constructions.

The feed-pump set between condenser and vaporizer, and which demands about three-fourths of 1 per cent. of the power developed, is designed and built with especial reference to avoidance of either leakage or what corresponds in the steam system to "water-hammer." The fact that it must handle a fluid liable at any moment to approximate the critical state between liquid and vapor compels also special care and peculiar construction.

Regulation was effected through the governor controlling the high-pressure cylinder of the combination. It proved satisfactory.

Condenser. SO_2 Cylinder. Low. Intermediate. High pressure.

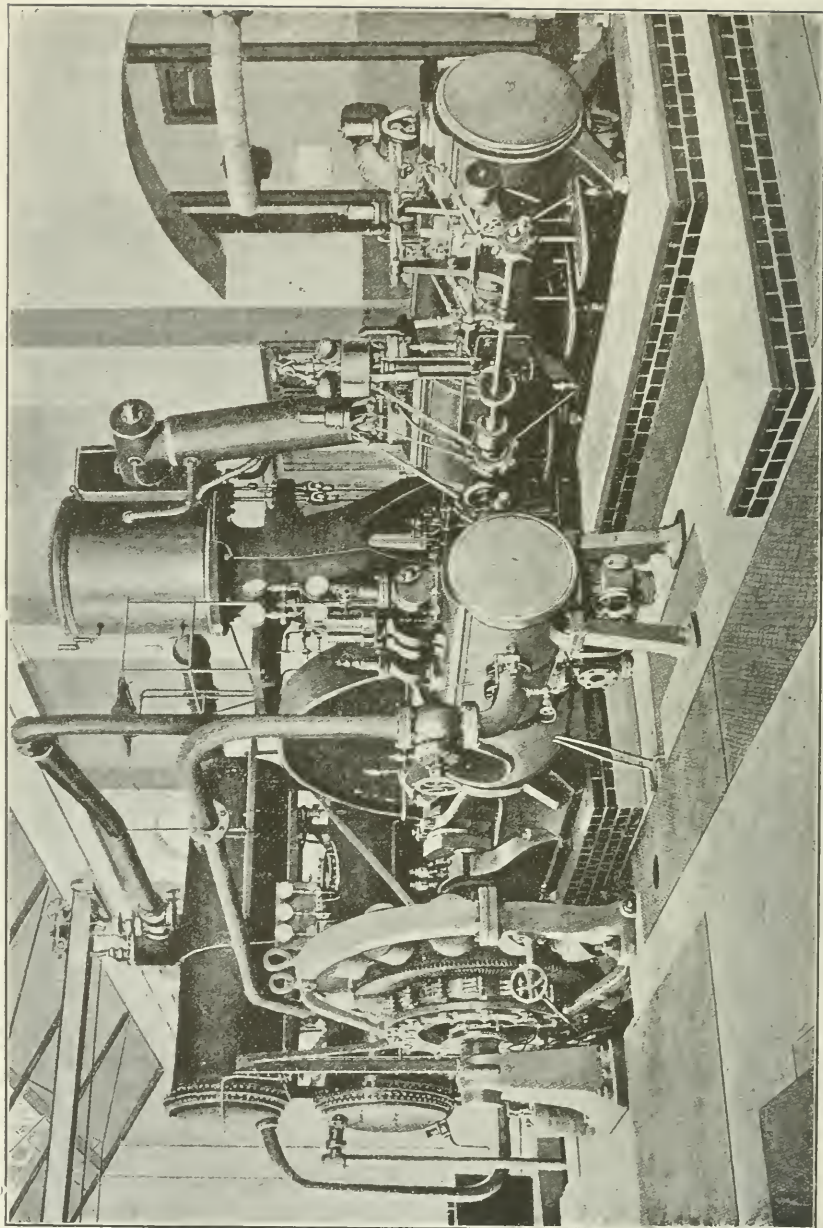


FIG. 7.—150 I.H.P. Engine of Technical High School.

In another engine, built for the oldest of the Berlin electric-lighting stations, the waste-heat engine is independent of the steam-engines. Rated at 175 I. H. P. it receives the exhaust-heat of steam-engines of 360 horse-power which demand in all about 18.35 pounds of steam per horse-power hour. It is so attached that the steam-engine may at any time be operated alone in case of accident or intentional detachment of the cold-vapor engine. The combination was operated and tested at various times after completion; but the most satisfactory data for the purposes

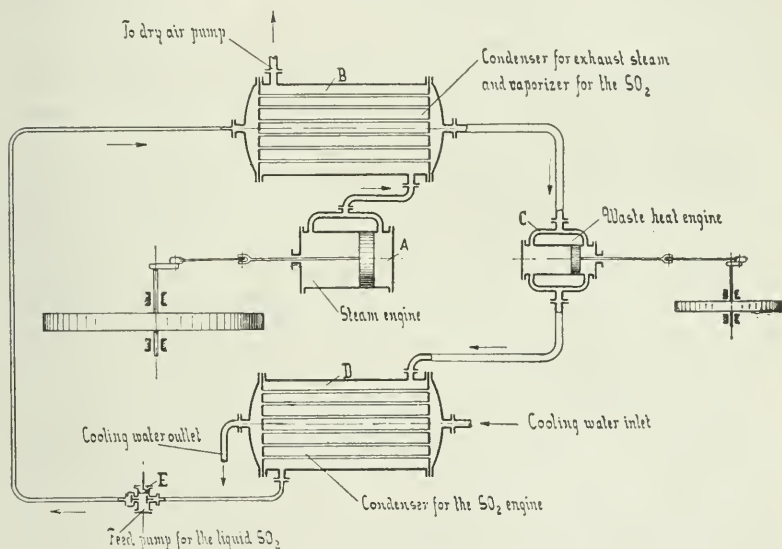


FIG. 8.—Scheme of binary vapor engine.

of the engineer were made after several months of working had brought the machine to something like a normal condition. The tests were made after the engine had become settled in its regime and in steady operation. The load was obtained from an attached dynamo and banks of incandescent lamps. The dynamo proved capable of an overload of 40 per cent. The quality of the exhaust-steam from the steam-engine was not determinable. All other data were probably as fully ascertained as could be desired.

The Use of Sulphur Dioxide, so long as free from air and

moisture, carries with it no objection on the score of injury to any part of the machine, whether iron or of other metal; and the construction may be similar in this respect to that of any other heat-engine. In those engines here described or referred to, the working cylinders are of cast-iron, and the minor parts of brass or bronze precisely as in the construction of the steam-engine. Modifications of size, proportions and details of design are, however, compelled by the change in the thermodynamic and physical and chemical properties of the working substance. Where the vapor employed is, as here, corrosive and irritant, or poisonous or inflammable, or otherwise objectionable as an element of the atmosphere, as, in fact, all the volatile substances thus used are, the vessels enclosing it must all be made absolutely tight, where practicable, and stuffing boxes must be made more perfect and must be more reliable, and their packings more durable than with the steam-engine. Where water and the secondary fluid must be conducted along opposite sides of the same metal wall, as in the condenser or in the vaporizer, it is absolutely necessary that the perfect fit of parts and tightness of joints shall be insured and permanently maintained.

The proportions of the vaporizer and of the condenser of the waste-heat engine are affected favorably by the ready transition of heat with this fluid, and they may be constructed with much less area of surface than similar parts for the steam-engine. The pumps handling the secondary fluid must be carefully designed for this special purpose, since they must usually be expected to work under a pressure which may in some cases be quite high, variations of temperature and pressure causing difficulties in operation, making the use of the "air-chamber" impracticable, but, on the other hand, this action giving an equivalent action, of which advantage may be taken to a limited extent. The secondary feed-pump brings no important load on the engine; its demand for power being reported at less than 1 per cent. of the total power.

The oily character of the secondary fluid, which is shared also by petroleum and probably some other available sub-

stances in some degree, is of peculiar value in the operation of the engine, for two reasons: the first being its insurance of freedom from friction without the introduction of oil into the working cylinder; the other, the reduction of internal thermal wastes by "initial" or "cylinder" condensation. The former reduces costs and difficulties of working; the latter the costs and waste of power-production. This latter property of these volatile fluids seems likely to prove one of the most important circumstances favoring their employment, either as primary or as secondary fluids. The ability to avoid the use of the common lubricants in the working cylinder also gives, as another valuable result, cleanness in the condensers and vaporizers, thus evading the common trouble, otherwise, of reduced efficiency in the action of heat-transferring apparatus, such as is observed as a consequence of the use of oil in the steam-engine condensers and steam-boilers, which latter often are subject to costly and sometimes fatal accidents from the collection of oil or greasy materials on their heating surfaces adjacent to the fuel-bed, or to gas-currents at high temperatures.

So little condensation occurs in the cylinders of the sulphur-dioxide engine that it has been found unnecessary to use the relief-valves on the cylinders even at starting up a cold engine. When it is considered that this waste in the steam-engine is rarely less than 20 per cent. in ordinary good practice, and often amounts to a multiple of that quantity, it is obvious that this property of the secondary fluid is one of great value and one which may even influence its more general adoption and possibly as a primary fluid in some cases.

The following is probably a sufficiently full abstract of the report made upon the combination of the 150 horse-power triple-expansion engine of the mechanical laboratory of the Berlin school with a 60 horse-power "waste-heat engine."

In this machine the high and intermediate cylinders are horizontal, tandem, and act upon the crank of the vertical low-pressure cylinder. The engine, supplied with a second crank—with rods, guide, and a frame with extension, for experimental purposes—the addition of a cold-vapor cylinder

was easy. The engine is provided with all experimental appliances, and may employ superheated steam, generated in an independent superheater close to the machine. The direct-driving dynamo was employed as load for the engine. The cold-vapor cylinder was attached to the frame. The vaporizer and condenser of the waste-heat engine were installed in place of the ordinary surface-condenser. The electrically-driven centrifugal pump, used as the circulating pump, and the vacuum pump were both retained.

The dimensions of the engines are :

Steam :

High-pressure cylinder diameter	270 mm. = $10\frac{5}{8}$ inches.
Intermediate " "	430 " = $16\frac{1}{2}$ "
Low-pressure " "	675 " = $26\frac{9}{16}$ "
Stroke of piston	500 " = $19\frac{1}{8}$ "
Normal speed	150 revolutions per minute.

Vapor :

Cylinder diameter	266 mm. = $10\frac{1}{2}$ inches.
Stroke of piston	500 " = $19\frac{1}{8}$ "
Speed	150 revolutions per minute.
Pressure assumed in design, pounds per square inch	215
Material of cylinder, cast-iron.	
Cylinder unjacketed and felted.	
H. S. of vaporizer, square foot	750
Cooling surface, condenser	1720
Pressure designed for maximum	285 for vaporizer.
" " " "	115 " condenser.
Material employed, iron.	

The Results of the Engine-Trials at the Charlottenburg school are condensed by the investigator into the accompanying table of data and resultant quantities. The steam was always superheated, except in test No. 8, when it was dry and saturated, affording a standard of comparison with the other cases. The temperature of the steam at the engine was usually about 300° C. (572° F.), that of the saturated steam 189.5° C. (373° F.), and the superheat 111° C. (200° F.). The temperature of the condenser of the steam-engine was adjusted so as to give satisfactory vacuum and at the same time a suitable vapor-pressure in the "vaporizer" and a good diagram at the secondary engine. The best work under these circumstances was done in Trial B,

TABLE VIII.—WASTE-HEAT ENGINE (AVERAGE VALUES).

Arrangement of Apparatus during the Test.											
Number of the Test											
Date of the Test											
a.	b.	c.	3.	4	5.	6.	7.	8.	9	10.	11.
25. 10. 00	21. 11. 00	23. 11. 00	12. 2. 01	14. 2. 01	14. 2. 01	15. 2. 01	15. 2. 01	16. 2. 01	20. 2. 01	20. 2. 01	21. 2. 01
Steam engine working triple expansion											
Water from the condensation traps led into the vaporizer											
Water from the condensation traps led into the vaporizer											
Superheated Steam											
dry saturated											
Superheated steam											
with small quantity of heating steam											
at half load											
Speed — r. m.	136.6	143.5	137.4	145	145	148	148	149	137	148	137
Volts at Dynamo	210	189.5	210	191	209	212	231	230	208.5	235.8	210
Amps from Dynamo	\$92	529	529	529	579	576.4	610	610	600.5	508.7	531
Temperatures	27.9°	30.4°	31.0°	30.6°	30.2°	30.4°	31.0°	30.1°	18.9°	33.2°	32.6°
Boiler steam — admission	136.5	156.5	158	156.5	156.5	156.5	156.5	148	150.5	166.5	157.5
Inlet pressure — High press. cyl. — lbs. per sq. in. above atm.	80	80.5	79	85	79.5	69	68.5	68.5	68.2	71.7	70.2
Percent vacuum in condenser	53.2	55.2	68.6	40.9	59.6	63.6	76.5	70.2	59.2	77.5	69.7
High-pressure cylinder	43.3	35.7	43.2	34.3	42.4	41.1	42.5	45.0	47.3	—	—
Intermediate cylinder	29.6	34.3	42.4	29.4	43.3	39.8	42.9	42.0	49.8	44.3	53.8
Low-pressure cylinder	13.2	12.2	15.2	101.6	145.3	144.5	161.0	163.2	156.3	121.8	145.5
Complete engine	165.2	140.5	188.1	146.5	198.0	199.4	213.3	177.5	256.2	164.9	188.5
Condensation from the vaporizer	—	—	—	—	—	—	—	39.7	—	—	—
Condensation from the steam jacket & receiver	—	—	—	—	—	—	—	—	—	—	—
Steam consumption in lbs. per hour	165.2	140.5	188.1	146.5	198.0	199.4	213.3	214.2	256.2	164.9	188.5
Total Condensation per H. P. ind.	12.5	14.2	12.2	14.4	13.6	13.8	13.2	13.1	16.4	13.5	13.4
Steam Engine.	55.6°	56.5°	66.5°	59.4°	59.5°	69.5°	68.4°	79.5°	67.5°	67.1°	68.6°
SV ₁ vapour Admission to cylinder	19.0°	18.8°	19.3°	15.0°	20.3°	19.8°	20.1°	18.7°	21.1°	18.1°	19.4°
SV ₂ liquid outlet from Condenser	9.8°	9.9°	10.1°	10.1°	10.1°	10.1°	10.1°	10.1°	10.1°	10.1°	10.1°
Circulating water — inlet	15.5°	15.7°	16.9°	17.7°	17.4°	17.4°	16.9°	18.4°	16.3°	16.3°	17.4°
Circulating water — discharge	13.2	12.8	17.2	110.9	142.2	187.7	186.3	192	186.6	177.7	181.4
SV ₃ pressures (above atmospheric in lbs. per sq. in.)	31.2	33.5	34.8	31.2	35.5	35.5	36.2	34.2	38	33.2	34.8
Condenser in lbs. per sq. in.	45.3	42.8	56.8	34.0	50.1	57.6	61.3	54.7	66.0	48.0	55.6
Output — H. P.	34.4	34.2	37.0	30.5	34.5	40.0	37.9	33.3	42.1	39.4	39.5
in percent of steam engine	—	—	—	—	—	—	—	—	—	—	—
Consumption of waste steam per H. P. per hour lbs.	36.5	34.8	33.2	47.3	39.5	34.6	34.8	—	38.9	34.4	33.9
Taken in to the Vaporizer	—	—	—	—	—	—	—	—	—	—	—
Indicated	17.4	168	211	132.6	195.4	202.1	223.2	217.9	222.3	169.8	196.1
Effective	151.8	143.8	177.2	114.2	174.3	176.2	202.9	201.9	201.9	150.8	186.2
Electrical	140.9	134	164.5	106.3	162.5	163.5	189.1	188.2	187.2	141.9	167.5
Total steam consumption per hour — lbs.	165.2	140.5	188.1	146.5	198.0	199.4	213.3	214.2	256.2	164.9	188.5
Steam consumption per H. P. per hour — lbs.	9.7	8.36	8.6	11.05	10.12	9.86	9.55	9.85	11.5	9.7	9.6
Total per hour	—	11.660	13.990	—	12.486	11.330	12.468	12.584	13.310	12.143	12.096
Quantity of circulating water in gallons	—	—	69.5	61.6	—	63.8	50.1	55.8	57.9	71.6	61.5
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Combined Engine	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	—
Per 1 H. P. per hour for the comb. engine	79.5	80.1	78	86.4	82.8	81	84.5	86	84.2	83.5	85
Electrical Output + I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	86.2	82
Mechanical Eff. — any B. H. P. + I. H. P.	—	—	—	—	—	—	—	—	—	—	—
Water-Heat-Engin.	—	—	—	—	—	—	—	—	—	—	—
Quantity of circulating water in gallons	—	—	—	—	—	—	—	—	—	—	

when the steam-engine demanded but 11.2 and the combined engine but 8.36 pounds of steam per horse-power hour, the latter figure breaking the "world's record" of its date, while the former is remarkably good for the size and type of engine. In this test the "waste-heat engine" added 34.2 per cent. to the power obtained from the primary engine.

When working with saturated steam, these figures become, respectively, 16.4, 11.6, and 38.9; showing a gain by the use of superheated steam of about three pounds, maximum, or, in B.T.U., about 20 per cent. for the combined engines. The compound engine, with large drop between cylinders, gave as good results, on the whole, if we except the two tests, *b* and *c*, as the triple-expansion machine; indicating, we may perhaps conclude, that with superheated steam the type of compound is a matter of comparative indifference, and that the compound with large cylinder-ratio is practically as satisfactory as the triple. Incidentally, it was noted that the use of superheated steam in these engines produced some leakage past the steam-valves.

The first three trials were made in November, 1900, the others in February, 1901; the latter showing the effect of use.

On reference to the table of data and results, it will be seen that all the reported trials of this extraordinarily well-constructed and most skilfully tested machine are remarkable for their admirably high efficiencies.

The average results of the best seven trials with superheated steam were the following:

Indicated horse-power, triple-expansion steam-engine	146.4
Plus indicated power of the waste-heat engine	52.7
<hr/>	
Total, combined engine	199.1
"Water-rate," steam-engine	12.80
Same for combined engine	9.43
<hr/>	
Gain by waste-heat engine	3.37
Percentage of gain of power	35.1
Net gain in economy of power-production	26.3

The points at once attracting notice on inspection of the figures are the high efficiency of the primary, the large gain by progressive superheating to the moderate extent here adopted, the previously unobserved, though not unanticipated, fact that the combined engine profits even more by superheat than the primary, the extraordinary gain by only 20° C. of superheat, in cases *a* and *b*, the small influence of the vacuum variation in these cases, the correspondence of high efficiency of the primary with high efficiency of the combined engine, the gain of 30 to 40 per cent. in power while gaining 25 per cent. and more in economy, and the high mechanical efficiency of the combination, 86.2 in the case of maximum thermal efficiency and up to 92 per cent. in other cases; the electrical output being from 74 to 85 per cent. of the I.H.P.

Comparing these results with the corresponding ideal cases, which would, with a Carnot cycle, give the horsepower hour on about five, and with the Rankine or Clausius cycle, as a minimum, about 6 pounds of dry and saturated steam per horsepower hour, or with 5,000 to 6,000 B.T.U., it is seen that the delivery of the engine here studied is very much more satisfactory than the rival primary form, but that it nevertheless still leaves a considerable range for further improvement. Its efficiency as a thermal engine exceeds that of the primary in proportion to the gain in aggregate power, which is shown in the table to amount to from 30 to 40 per cent. The primary has an efficiency approximating 20 per cent., while the binary machine gives a combined efficiency of about 27 as an average. The net efficiency, thermal and dynamic, together, is thus about 23 or 24 per cent. That of the ideal cycle, as a purely thermodynamic system, for the observed range of temperature, is about 50 per cent., of which about 10 per cent. is due to the superheat obtained in the average case taken.

The best engines of the time, so far as investigation has gone, give a comparable efficiency, in the actual case, of slightly above 20 per cent. and, in the case of the Hall & Treat engine, with abnormal steam-pressures (300 to 600 lbs)

and a quadruple expansion engine, under exceptional circumstances, the ideal efficiency was 0.28; the ideal engine demanded 8,000 B.T.U. and 6.86 pounds of dry steam per horse-power hour, while the real engine did its best work at the lowest pressure and demanded about 225 B.T.U. per I.H.P. per minute, 13,500 per hour and 9.27 pounds of slightly superheated steam, developing but 11 horse-power with a mechanical efficiency of 87 per cent.*

In the engine trials reported, it was usually made a condition that the gain by the use of the secondary fluid should not be at the expense of the efficiency of the primary engine. The increased power and the gain in economy are thus measures of the advantage to be secured by the addition of a "waste-heat engine" to the ordinary steam-engine when the latter is itself a very economical machine and much more so than the average engine as constructed by even good builders.

In these trials it was incidentally noted that the best effect was secured when the steam-engine was operated with a somewhat imperfect vacuum, 70 per cent. or about 21 inches. Either a better or a worse vacuum reduced the efficiency of the combined engine. The gain in the steam-engine, operated independently, was but about 3 per cent. when the vacuum was improved from 68.5 to 92 per cent., 21 to 27 inches. The experience confirms the well-known principle, that with every engine the best vacuum is determined by the cost of its production as well as by the value of the gain secured by it.

The secondary engine was found to be subject to but slight loss by cylinder condensation; this is to be at least in part accounted for by the narrow range of temperature worked through, and probably also in part by the comparatively small susceptibility of the oily fluid employed to heat-exchange with the metal of the cylinder. The sensitiveness of the secondary fluid to changes in the temperature of rejection of heat from the primary engine is seen in

* "Promise and Potency of High-Pressure Steam." "Transactions Am. Soc. M. E.," Vol. XVIII, 1896, No. 718.

the data furnished by these trials. The rejection of heat from the steam-engine, when its vacuum was held at 24 inches, produced a pressure in the vaporizer of the secondary machine of 156 pounds per square inch, while with a vacuum of 21 inches, the gage showed 199. It was also observed in all these trials that the transmission of the secondary fluid was impeded by friction in the piping and that it is desirable, in designing this class of machinery, that the velocity of flow through steam and exhaust-pipes and through valve-ports, should be low relatively to the rates of flow of steam in common practice. The section of the passages should be made proportionately large. This feature is economically important, and the adjustment of sizes of piping to maximum economical result is one of those problems remaining to be solved by experience.

It is seen, on reference to the results recorded, that the secondary engine added to the output about 1 horse-power for each 32 pounds of steam used in the primary per hour. The consumption of heat in the secondary was 7,800 calories per horse-power hour, which is excellent economy when the small temperature-range is considered. With high exhaust temperatures in the primary engine, the water of condensation may be used profitably as feed-water and the steam condensation from the jackets and receivers may be employed to furnish energy to the secondary, affording a very sensible advantage. Employing superheat in the steam-engine, the relative value of the secondary engine is increased, since this infers the rejection of the exhaust at a higher temperature, though in smaller quantity, than when using saturated steam. On the other hand, these trials throw into relief the fact that generally increased efficiency gained by one expedient makes unnecessary the employment of another, and the compound engine would seem to be usually a better primary than the triple-expansion under conditions approximating those here illustrated. This is shown in tests Nos. 9 to 12 inclusive; but just how far the relatively high cylinder ratio is secured by this cutting out of the intermediate cylinder of the triple to form the compound cannot be here determined, although it is clear that

the compound performed about as well as the triple under the conditions observed. It is further to be noted, however, that when cylinder condensation is extinguished by superheating, the performance of the two engines should be practically the same, the *raison d'être* of the multiple-cylinder engine having been thus removed and the advantages of the compound made simply those of kinematic action and those of construction due to the equalization of pressures in the cylinders and on the crank-pin, when expansion-ratios are high.

The low range of temperature of the condensing water infers a large volume; but it is obvious that the same would be true with similar conditions in the steam-engine. In so far as a larger volume is demanded, it is due simply to the fact that it may be profitable to secure a lower final temperature of rejection of heat from the system than from the steam-engine alone. The quantity used in these trials ranged from about 33 to 55 gallons per hour per I.H.P., while 40 gallons may be taken as the average consumption in the primary engine operated under usual conditions. The low temperature-range of the cooling water compels a corresponding large area of cooling surface, and both the vaporizer and the condenser have in these engines comparatively large size and volume as contrasted with similar constructions for handling steam. The proportions recommended, 5 to 7.5 square feet per I.H.P. in the vaporizer and 20 to 25 in the condenser, are enormously larger than the proportions adopted, for example, in marine practice for steam-engines of the highest class.

The accompanying diagram illustrates the distribution of working fluids in the triple-expansion system as supplemented by the waste-heat engine. This diagram was taken during the progress of Test No. 6, in which, while the lowest temperature of heat and fuel was not reached or highest efficiency attained, an excellent adjustment of the several elements of the combination was illustrated, and this combined diagram may be taken as a good exemplar of its class. The individual, separate diagrams for all four elements of the combination are seen in the succeeding figures, and are

those from which the combined diagram has been constructed.

The combined indicator diagrams here given exhibit the distribution of steam and that of the secondary fluid where the intermediate cylinder was cut out to form a compound with a secondary fluid auxiliary. The steam being moder-

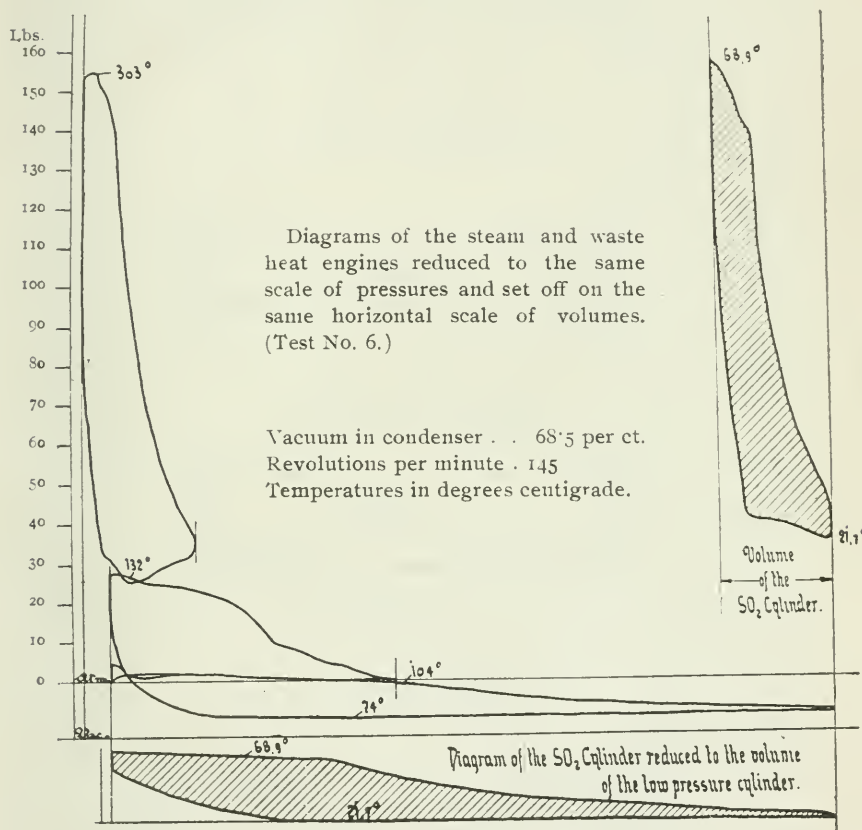
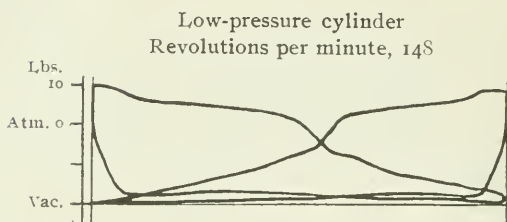
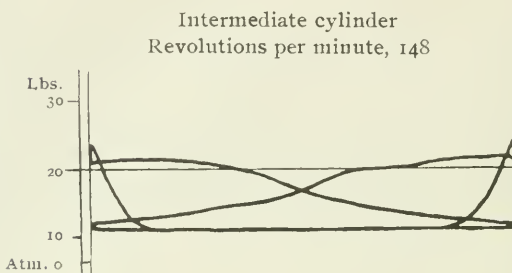
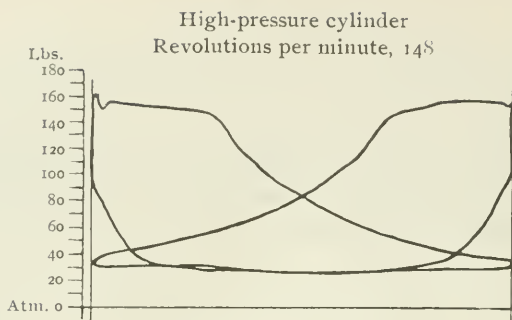


FIG. 9 —Combined diagram. Triple-test 6.

ately superheated, the consumption was practically the same with the compound as with the triple which it superseded, and the gain by the employment of the secondary fluid engine was no less.

Superheated Steam (300°C. , 572°F.) was employed in the steam-engine, and it was endeavored to secure the highest



Steam diagrams.

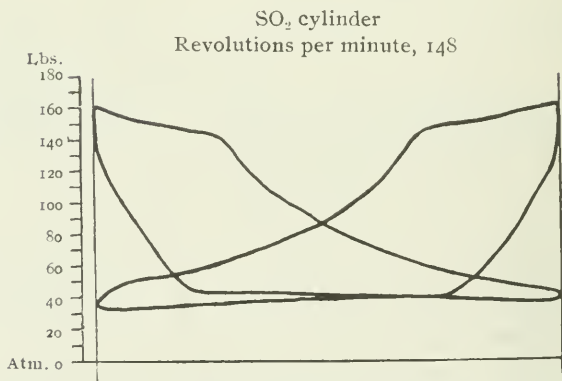


FIG. 10.—SO₂ Diagrams.

practicable efficiency in that element of the combined machine. Its best work is reported to have been done with 11.2 pounds of steam per horse-power hour and while discharging 34.2 per cent. of its energy into the waste-heat engine, and thus reducing the consumption to the unprecedented figure of 8.36 pounds for the series-system. The steam-pressure was about 156 and, in another test, with 158 pounds pressure, the expenditure was 8.6 pounds. The usual result ranged from 9.5 to 10, without outside figures of 11 and 11.5, with reduced superheat, and in the latter case with none. The best work was done with a vacuum, as expressed in the report, of "70 per cent.," 21 inches, and the evidence was thought conclusive that the waste-heat engine was subject, in an extraordinarily small degree, to cylinder-condensation, confirming earlier and direct tests of that quantity. As between 21 and 24 inches vacuum, the pressures in the vaporizer ranged from 156 to 199 pounds. Thus not only the temperature ranges but also, in a striking degree, the pressure-range, of the waste-heat engine influence the net economy of the combined machine.

The losses of energy due to friction of flow of the secondary fluid through connecting pipes were found to be very large, as compared with those affecting the movement of the comparatively light water-vapor. The loss of pressure between vaporizer and cylinder ranged from 28 to 40 pounds per square inch, and the reduction of the area of the indicator diagram from the latter amounting to from 16 to 24 per cent. It follows that velocities of flow in the connecting pipes must be made much less, in practical use of these fluids, than for steam; an exceedingly important deduction as affecting the design of this class of engine.

Another interesting revelation by these tests is the advantageous effect of trapping the water of jacket-condensation into the vaporizer. This gain supplements, according to the reports, that derived from use of feed-water, from the discharge of the vaporizer, at temperatures of from 140° to 160° C. (284° to 320° F.) at the boiler, affording a gain of about 7 per cent. over the steam-engine in ordinary cases.

Still another striking fact comes of the analysis of these

trials: Since the use of superheated steam reduces the cylinder condensation in the steam-engine, while, at the same time, the exhaust heat-waste slightly increases and the supply of heat-energy to the secondary fluid becomes somewhat increased, it follows that the use of superheated steam in this combination becomes doubly advantageous, instead

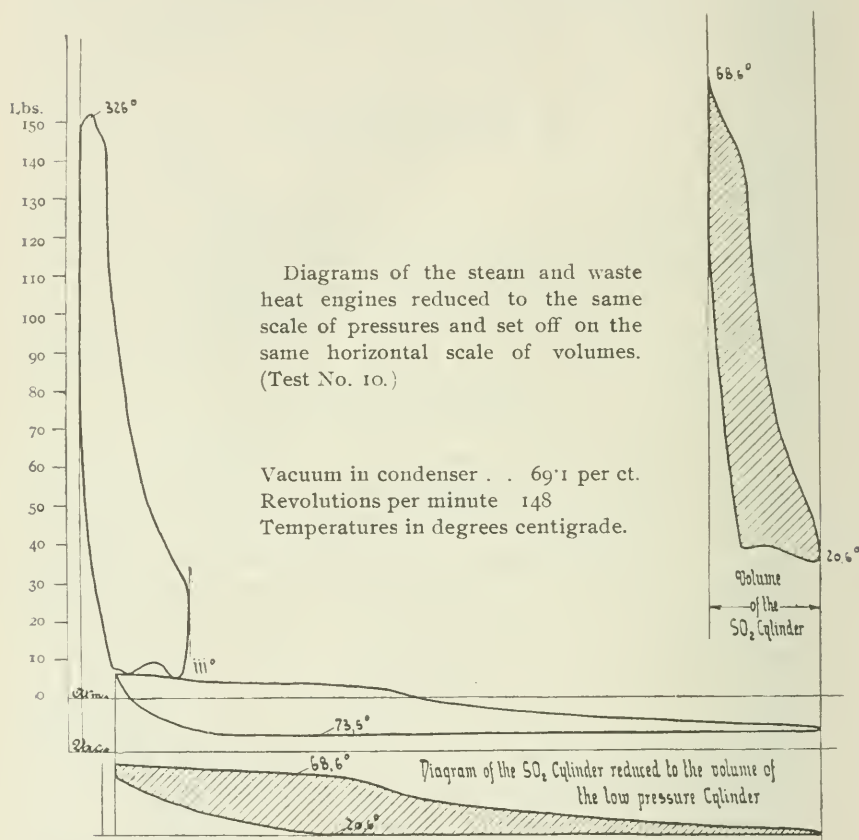


FIG. 11.—Combined diagrams. Compound.

of, as in the primary fluid alone, less advantageous with reduction of exhaust waste by the system of compounding. The triple-expansion engine is thus given a wider range of application commercially. Experiments show that, as was long since noted by the writer, in multiple-cylinder steam-engines, the employment of the one system of reducing

wastes makes the use of the other less advantageous, and it is often questioned whether, with superheating, the compound, or even, with high superheat, the simple engine may not be financially more desirable than the triple or quadruple engine. In the present case, it was found that, when the intermediate cylinder was cut out, the economy of the resulting compound was as high, using superheating steam, as with the triple in use. It is concluded that, with superheating and a supplementary waste-heat engine, the compound engine is on the whole more desirable than the compound.

Economy is effected also in the use of cooling water. Since the utilization of heat is more complete, the rejected heat becomes less, and a smaller quantity of cooling water, if properly employed, is demanded for the binary-vapor engine. On the other hand, if cooling water can be obtained at small cost, it is possible to secure a larger gain by its free use, and it is advised to increase the supply 25 per cent. above that of the steam-engine as customarily operated. It is evidently advisable to investigate this question wherever proposing to employ the combined machine.

The indications of these investigations are that surfaces in the vaporizer and the condenser should be made about 7.5 and 20 to 25 square feet per I.H.P., respectively, when as effective as those here employed.

Considering the employment of the "cold-vapor engine" in other situations than as adjunct to the steam-engine, it is shown that the production of power, from the waste-heat of the chimney-flue of the steamboiler, with forced draught from the gases of the blast-furnace, and from the gas-engine particularly, it will be found that this choice of a working fluid for the heat-engine adapted to such special purposes may give large promise, especially as the "waste-heat engine" converts a large percentage of the heat supplied it into mechanical energy.

The larger the installation, the greater should be the advantage of the binary-fluid system.

The financial side of the question of adoption of this system has been somewhat illuminated by these investiga-

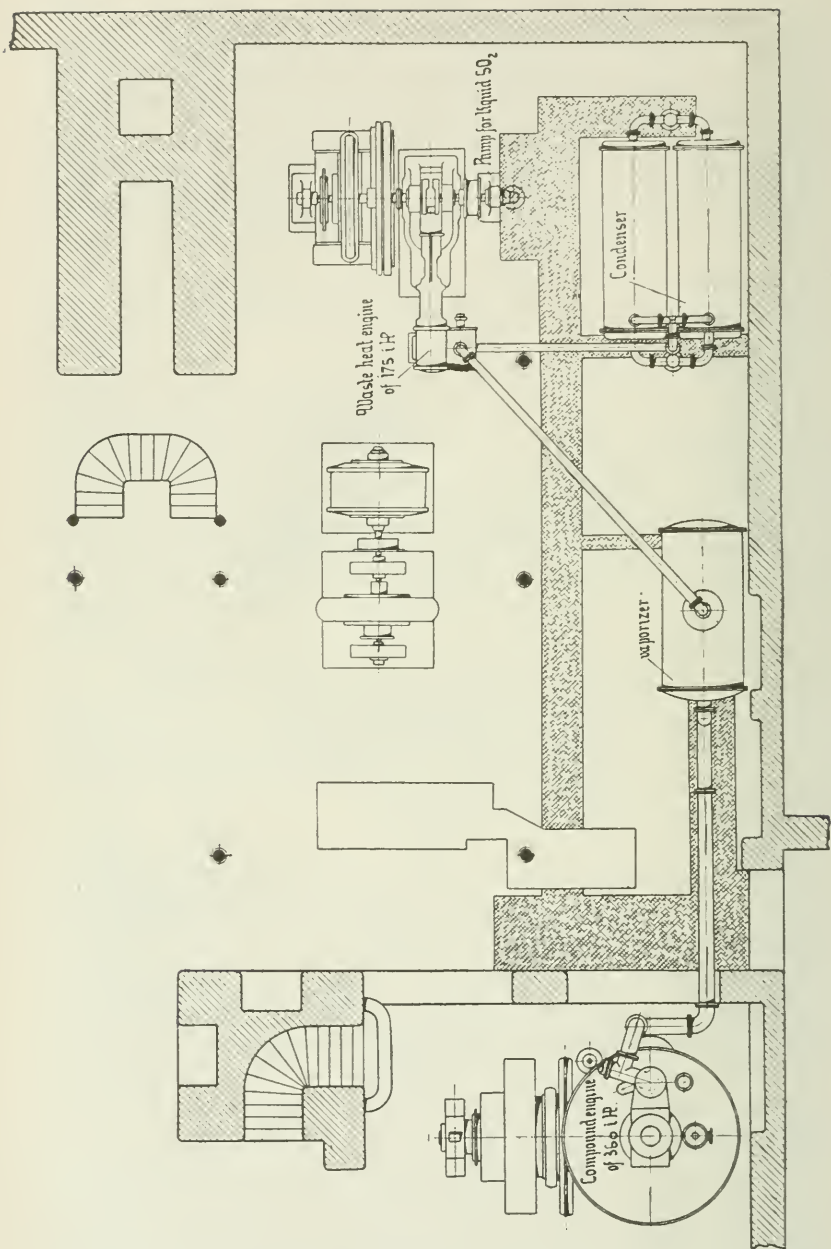


FIG. 12.—Detached "waste-heat engine."

tions. The costs of plants of 1,600 I.H.P. on this system and on the usual system of triple-expansion steam-engines, are reported to be, in Germany, respectively 212,000 and 206,000 marks—practically the same. Including costs of boilers and connections, the costs should be even less for the binary system, in consequence of the lesser boiler-power demanded. A similar comparison of costs of the binary-vapor and the corresponding gas-engine construction gives similar results for 175 I.H.P.; both falling under 50,000 marks for the whole plant ready for operation. The saving in fuel, in the former case, for 1,600 horse-power, is estimated at 6 per cent. on the first cost, allowing the consumption of the steam-engine to be, as is now guaranteed by builders, 10.05 pounds of steam per horse-power hour and 7.76 for the binary-vapor machine. Experience only, however, can determine just how far this relation will hold for the life of the plant when all costs, including interest, maintenance and replacement, enter the account. It also remains to be determined by experience whether the figures here assumed may be safely guaranteed in commercial work generally.

CONCLUSIONS.

From what has preceded, it is probably safe to adopt the following:

(1) It has been fully established, by frequent and prolonged experiences with multiple-vapor heat-engines, that they permit the combination of the advantages of the single-fluid multiple-cylinder engine with those of decrease in the cylinder-condensation waste of the single fluid, steam, in the ordinary engine and some gain in mechanical efficiency due increased mean effective pressure at a given temperature-range of engine cycle.

(2) That the binary-vapor engine to-day, as in the days of Rankine and Du Trembley, maintains a lower record than does the single-fluid engine, and this record now stands at, as reported, 8.36 pounds, less than 4 kilograms, per horse-power-hour.

(3) That the question of the practicability of utilization of this form of heat-engine in the industries must be, as

always, ultimately determined by financial results—by its capability of adding to the dividend-paying power of the enterprise into which it may have been incorporated. This means, practically, its freedom from liability to dangerous or annoying or costly accidents and interruptions of its operation.

The thermodynamic aspect of the question is perfectly well determined and understood among engineers, and this practical question can only be decided by time and experience and further experiments in design, construction and operation.

The practical identity of the efficiencies of the triple-expansion and compound engines, when employing moderately superheated steam, the total ratio of expansion and the initial pressures being the same, as in these experiments, has special interest as confirming the deductions which may be made from many other independent experiences—that the internal wastes of the engine being quenched by superheating or other method, the special advantage of the series-engine in this respect disappears. With sufficiently superheated steam, the simple engine would become the equal of the compound or of the triple—so far as this efficiency goes—and yet the gain by the employment of the waste-heat engine would not be in the slightest degree reduced. In fact, should superheating be carried to the extent of increasing the temperature of the steam at exhaust, its usefulness would increase with rise in the final temperature of the exhaust-steam. The value of the ordinary system of compounding is thus decreased while that of the “waste-heat” system is increased, by the adoption of superheating; the series-engine loses value while the series-fluid gains. No known expedient, in fact, can supersede the latter method of extending the thermodynamic action and temperature-range of the steam-engine. Should the commercial aspect of the case prove satisfactory, it may be expected to inevitably take its place as a standard available form of heat-engine. Its theory and thermodynamic characteristics cannot be criticised.

Summarizing the main facts of the investigation, we

may conclude that the best work of the best builders of the steam-engine may be to-day taken as measured by an expenditure of about 11 pounds of dry steam per horse-power hour, corresponding to about 11,000 B.T.U. per hour, which means the heat stored in about three-fourths of a pound of best coal as measured in the boiler. The records of engines employing other fluids than steam have usually shown a better performance than similar engines using steam under similarly favorable conditions, and the "Heat-Waste Engine" has availed itself of the wastes from a steam-engine of the highest type, doing its work better than the average engine of the best builders under most favorable conditions, and has thus reduced the consumption of heat, steam and fuel, from figures approximating those just given to less than 10,000 B.T.U., 8.35 pounds steam, moderately superheated, and to the equivalent, on the above basis, of about two-thirds of a pound of best coal per horse-power per hour as shown on the indicator diagram, and to figures about 10 per cent. larger for delivered power, thus breaking the world's record by a very remarkable margin.

It will be also noted that this gain is produced by following the idea of Cotterill, the writer, and others; of availing ourselves of the opportunity to depress the lower limit of useful temperature-range of the cycle, and of the fact pointed out most clearly by Wood: that differences in efficiency of cycle may be due to differences of physical constitution of working substance in other than the Carnot cycle; as well as of the principle—which has been for years enunciated by the writer and probably recognized by others—that maximum availability of working fluid is obtained when the superior limit of practicability of control of both temperatures and pressures is the same for both, and when, similarly, at the lower limit, the minimum utilizable temperature of the expanding fluid is accompanied by pressure of maximum availability, with, further, a minimum back-pressure.

The ability on the part of the designer, and in perhaps some degree, also, on the part of the operator of the binary

engine, to adjust the pressure, vacuum or plenum, as may prove best, in the vaporizer, to the point of maximum economic effect, may be accepted as one of the valuable elements of this problem, in construction and use of the heat-engine. There must necessarily be a surface-condenser in which to condense the exhaust-steam and to transfer its heat to the secondary element; and this permits the adoption of whatever tension of vapor in that vessel may be found, by experience or more exact experimental investigation—all things considered—to prove best.

The same principle and the same statement apply also to the condenser of the secondary engine, where it may be found desirable to adjust the pressure, similarly, with any given engine and to also adjust the tension of the exhausted vapor to the best conditions for the use of different secondary fluids. Both primary and secondary fluids must be worked in closed cycles, in all such series engines, and the pressure of the external atmosphere disappears as an element of the problem.

In construction, the secondary engine is proportioned to deliver about 40 per cent. of the power of its primary, as a rule, the precise dimensions depending upon the waste-heat to be utilized by it and the relative costs of gains and losses in the primary as well as in the secondary. The adjustment of the two elements of the series-engine is ultimately controlled, as is every engineering problem, by the commercial test; and that final adjustment is sought to be secured which, being attained, any deviation therefrom will produce a greater loss than gain; and any gain secured will be more than counterbalanced by some incidental accession of waste—thermal, dynamic or financial.

It is particularly desirable, with these fluids, to employ forms of valves and gear which shall be easily made and kept tight and shall not cause difficulty in keeping tight all stuffing boxes. Probably the plan employed for many years past on very high-pressure engines, as by the Messrs. Perkins, and by the builders of the Berlin engines here discussed, of making the stuffing boxes exceptionally long, and of rotating the valve-stems rather than moving them

longitudinally will usually be found best. The device of the "lantern-brass" of the old Cornish construction of piston-rod packing is another suggestion from older practice, which may be found valuable for these later constructions, where it can be modified to meet the needs of the new system. In the Berlin engine, puppet-valves were adopted with rockshafts as lifters. The piston-rod stuffing box presented an interesting problem; but it was finally constructed in such manner that no working fluid reached the outer end at all, the construction being double and the outer portion being made to employ grease as the substance acting as the outer seal. It was also found practicable to entirely prevent the passage of the grease from the stuffing box into the cylinder.

The apparatus of heat-exchange between primary and secondary fluids, and between secondary fluid and the water for condensation and disposal of finally rejected heat, may be designed with from 10 to 15 square feet per horse-power of secondary engine, and 30 to 40 feet, respectively, for vaporizer and condenser. In the Berlin engine, the areas were 753 and 1,720 square feet, and the power indicated ranged from thirty to sixty, the best work being reported when the secondary engine developed about 60 horse-power and about 35 per cent. of the power of the primary machine. They were made of iron, proportioned for pressures of 285 and 115 pounds, respectively, and so arranged that they could be inspected and cleaned without removal of the sulphur dioxide from the system. A suitable arrangement of valves permits cutting off the reservoirs containing the secondary fluids when it is desired to inspect the working cylinder. Safety-valves on both reservoirs—the one between vaporizer and condenser, the other between condenser and the outer air—insure against dangerous pressures.

It is evidently advisable, as is usually entirely practicable, to so design the two elements of the combined machine that the steam-engine may be employed independently should it be found necessary to cease operating the secondary engine, for any reason, or to take it out of the system for general inspection and repair.

In making such a combination, it is seen that the value of the secondary machine increases with the wastefulness of the primary, to which it is to be attached.

Since the contact of sulphur dioxide with air and moisture induces prompt oxidation to sulphuric acid and equally prompt action of the acid upon all common materials of construction, absolute tightness of the vessels containing it and perfect protection against introduction of either air or vapor of water into working cylinder, vaporizer, condenser or pipes, is necessary. Introduction of atmospheric air is usually not to be apprehended during operation, as the pressure of the secondary fluid is commonly at all times in the cycle above that of the external air. Good design and construction may be relied upon to prevent the introduction of water or steam. Professor Josse reports that one of his engines had been examined after a year of constant contact of water and sulphur dioxide with the opposite sides of its condenser surfaces without trouble, and another had at last reports been in use nine months with equally satisfactory result.

The great sensitiveness of the pressures of the volatile fluids to heat-exchanges is a minor disadvantage in their use, as the pressures are liable to fluctuate much more rapidly than is the case with steam; and careful provision must be made against sudden and dangerous increase of pressure with any quick variation of heat-supply as, with a primary fluid, the result of sudden increase in temperature of fire or, with the secondary fluid, a sudden and unusual discharge of heat from the main engine through change of its load.

The accompanying figures show the arrangement of the designs prepared for a set of 1,600 horse-power binary-engines on this general plan. It is not important, however, that this particular arrangement should be adopted. The binary engine offers quite as much freedom in location of parts and their relative distribution as the condensing steam-engine of similar power, or as the multiple-cylinder engine of standard forms. The two elements of the binary machine may be set on a frame or they may be placed inde-

pendently, except as to connections, as is sometimes the case with a compound steam-engine, the high-pressure element of which may be at one point and may drive one section of machinery, while the low-pressure element may be an independent engine, as to construction, placed apart and em-

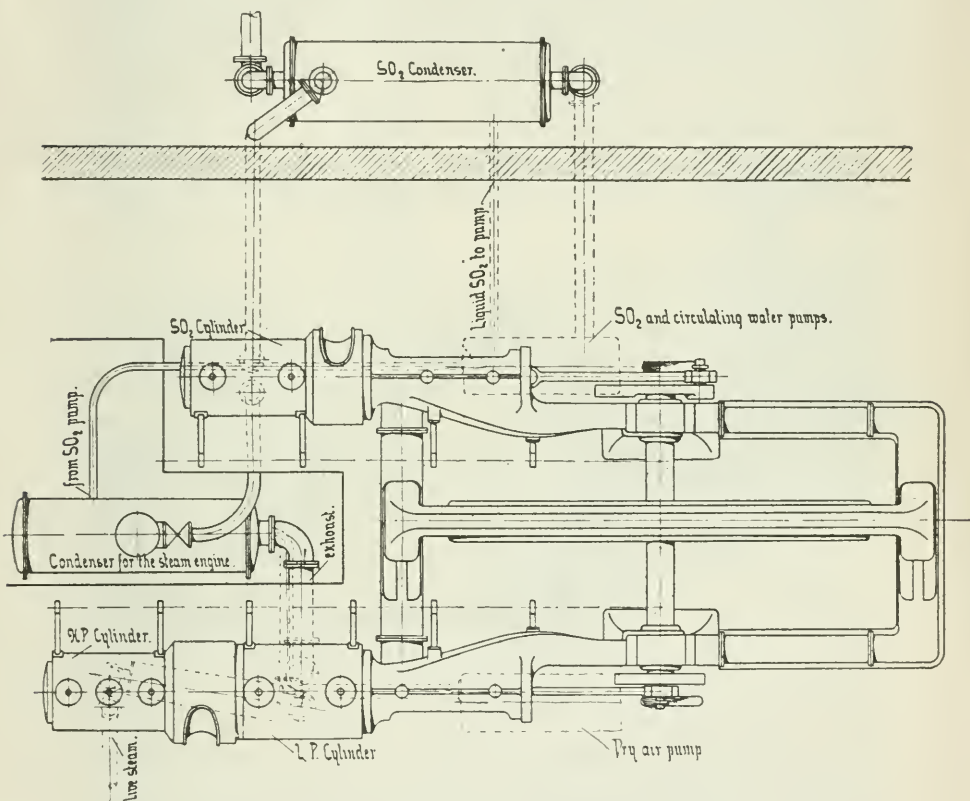


FIG. 13.—Binary engine. 1,600 I.H.P.—Plan.

employed in driving another section of the machinery of the establishment.*

The Financial Problem is here, as always, the finally determining element of the case. If the ultimate and complete

* This disposition was actually made by Mr. Charles E. Emery, where circumstances were especially favorable.

reckoning exhibits a net gain of sufficient magnitude to justify a proposed installation, the new device will certainly be adopted ; if not, whatever the apparent gain in thermodynamic efficiency, it will never be successful.

The costs of construction of the binary-vapor engine of the Berlin type is reported to be substantially equal to that of a steam-engine of similar power, while its consumption of fuel should be reduced to two-thirds or three-fourths that

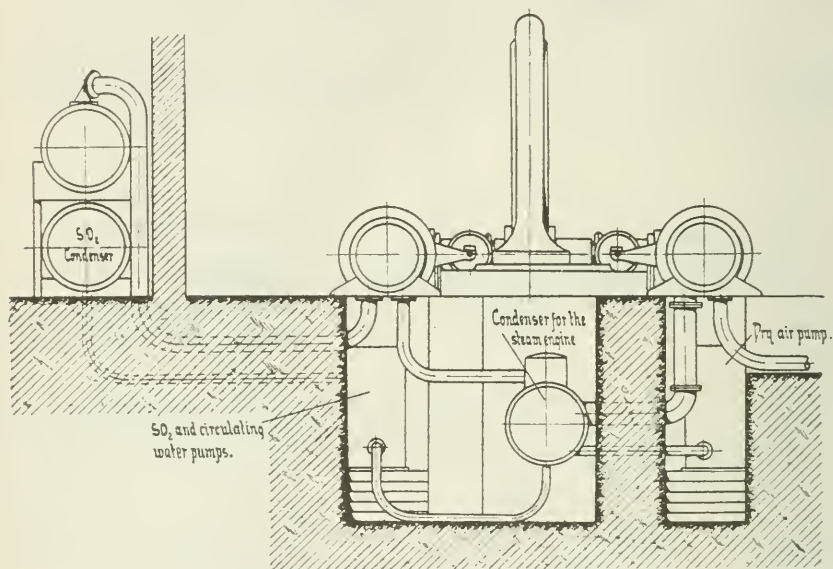


FIG. 14.—Binary engine. 1,600 I.H.P.

of its rival. The estimates made by the builders of the machine reported on for a series-engine of 1,600 horse-power, indicate substantial quality when comparing a triple-expansion steam-engine with a compound steam-engine supplemented by a "waste-heat engine ;" reckoning the former as inclusive of 1,600 horse-power of boilers, the latter requiring 1,200 horse-power. The actual difference in the estimates is 3 per cent. on total cost in favor of the steam-engine. A similar comparison of a triple-expansion steam-engine with an equivalent 175 horse-power gas-engine indicates a difference in favor of the latter amounting to about 4 per cent.

The larger machines are estimated at about 125 marks (\$31) per horse-power; the smaller at something less than 300 marks (\$75) per horse-power. For the larger plant, above described, the cost of fuel in operation is estimated at about 12,600 marks (\$3,150) per annum, less for the binary machine; for the smaller plant, the gain should be in somewhat larger proportion, as smaller sizes are more wasteful than large, and the waste of heat, capable of utilization by the secondary element of the binary-vapor engine, should be greater. The gas-engine would seem to offer still larger opportunity for economy, as it competes with the steam-engine, and yet has a still larger proportion of waste to power, its higher thermodynamic efficiency being compensated largely by its high temperature of exhaust.

The series-engine, in which other than steam-engines constitute the primary element, as with a gas-engine combined with an ether-engine, or where the waste-heat engine derives its supply of energy from other sources of waste than the rejected heat of a primary heat-engine, as in utilizing the heat of blast-furnace gases, or that of heating furnaces, or, in fact, any source of low-temperature heat from which the steam-engine cannot derive energy profitably, remains an untried but, probably, in many cases, a promising scheme. The outcome of these experiments has led to the suggestions that even hot-mine waters may be used, as in Chile, as a source of such energy. The chimney of the steamboiler carries off, usually, 20 per cent., often more, of the heat of combustion and, by utilizing a mechanical system of draught, this may be rendered available for power purposes. The rejected heat of the gas-engine usually amounts to from one-half to two-thirds of the total, and this, as has often been proposed, may be employed in any form of successful heat-engine employed as a secondary element, increasing the delivered power in some such proportion as has actually been attained, with the steam-engine as a primary.

It remains an interesting question whether the costs of construction may not be considerably reduced by the adoption of much lower areas of surface-condensers than were in this case employed. The fact is familiar to all who have to

do with marine engineering, that it is usually amply sufficient, with the marine steam-engine, to provide about 3, and sometimes as low as 1 or 2 square feet of cooling surface per I.H.P., while the work to be done and the weight of steam to be handled per horse-power is commonly considerably greater than with the combined engine as here reported. It is true, that in the latter the heat must be twice thus transferred, instead of, as in the steam-engine, but once; but it is here reported that 5 to 7.5 feet should be provided in the vaporizer, and about four times these large figures for the final condensation. It would seem probable that it may be ultimately found that proportions far nearer those which long experience has given the condenser of the steam-engine may be safely and economically adopted for the combined engine.

Should the figures here deduced be confirmed by longer experience, it would seem to be good evidence of a much greater reluctance to heat-transfer on the part of the secondary fluid than is exhibited by steam. On the other hand, this deduction has already been drawn from other experiences in the use of the volatile fluids, especially with ammonia and with carbon-disulphide. This would account for the large demand for cooling water.

The ultimate test of efficiency also remains to be applied: the absolute and relative costs of power-production under these various conditions and with the various combinations of primary and secondary engine, measured in thermal units per unit of power. This happens to be a case in which this final reduction to the ultimate measure is essential to exact conclusions.

If it be assumed, as believed by the promoters of the "waste-heat engine," that, "constructively, the engine is now so far perfected that nothing stands in the way of its employment," and that "the prejudices, existing especially against the employment of sulphur dioxide, are entirely without foundation, *when the apparatus is in skilful hands*" (the italics are introduced by the writer) new installations may be profitably constructed on this plan, and the gain by introduction of the supplementary engine in existing and

even fairly economical plants may be expected to be still larger—always provided later experience shows depreciation, accident and interruption of operation by all the various causes incidental to the use of prime movers to be no greater than with well-constructed stem-plants.

INSTALLATION COSTS—COMBINED STEAM-WASTE HEAT PLANT OF 1,600 HORSE-POWER.

The cost of the engine proper, consisting of compound steam-engine of 1,200 I.H.P. and a cold-vapor cylinder of 400 I.H.P., together 1,600 I.H.P., for 72 revolutions per minute and including a sulphur-dioxide pump, vacuum pump and cooling water pump, for the price of	\$31,250
One vaporizer for the cold-vapor engine	2,500
Two condensers	6,000
Valves	1,000
Extra for pipe-system	1,750
First supply of sulphur dioxide500
Two steamboilers with superheaters for 1,200 I.H.P.	8,000
Total	\$51,000

On the other hand, the costs of a triple-expansion installation for 1,600 I.H.P. and 72 revolutions per minute, consisting of high-pressure, intermediate and two low-pressure cylinders, including two jet condensers and two air-pumps, would cost, when constructed by the same steam-engine builder	\$37,500
Two boilers and superheaters for 1,600 I.H.P.	14,000
Total	\$51,500

Book Notices.

Geschichte der Moränenkunde von Dr. August Böhm Edlen von Böhmersheim, Privatdocenten an der K. K. Technischen Hochschule in Wien. Mit 4 Tafeln und 2 Textfiguren. *Abhandlungen der K. K. Geographischen Gesellschaft in Wien*, III. Band 1901, No. 4. Wien 1901, R. Lechner (Wilh. Müller) K. u. K. Hof u. Universitäts-Buchhandlung.

This important work covers 334 small quarto pages and is an exhaustive presentation of everything known to-day about moraines. It is divided into four principal parts—the history of moraines; the glacier conference of August, 1899; the classification of moraines; and an elaborate bibliography.

Dr. v. Böhm traces the subject of glaciers back to Seb. Münster in 1544. but he finds the first suggestion of moraines, under another name, in a curious poem of H. R. Räßmann in 1606, "Talk Between Two Mountains." The term moraine occurs first in a paper by Besson (1777-1780), who heard the word in Savoy, but who wrote it *maréme*, in which spelling he was corrected

by De Saussure (1796). Dr. v. Böhm treats at length of all the well-known writers who have touched on moraines, such as DeLuc, Rendu, Charpentier, Agassiz, Escher v. d. Linth, Forbes, Dollfus-Ausset, Tyndall, etc., but it would be impossible to give briefly a tithe even of the names of the numerous writers and observers whose observations and theories he carefully notices.

Besides a lengthy criticism of the glacier conference and of the various theories now held about moraines, Dr. v. Böhm gives his own views of moraines and offers a system of classification to help clear up the terminology of the subject. His book is certainly a valuable and original contribution to the knowledge of glaciers and it deserves the attention of all glacial geologists.

E. S. BALCH.

American Rifleman's Encyclopedia, being a collection of words and terms used by riflemen of the United States, with definitions and explanations for rifle-shooting. Compiled by A. C. Gould, Editor of *Shooting and Fishing*. 12mo, pp. 137, paper covers. The Peters Cartridge Company, O., N. D.

The principal contents of this booklet is clearly expressed in the sub-title. In addition to the glossary, the volume contains much miscellaneous information of value to those interested in rifle-shooting. W.

Übungsbeispiele für die Electrolytische Darstellung chemischer Präparate. Zum Gebrauch in Laboratorium für Chemiker u Elektrochemiker. Von Dr. Karl Elbs, o. Prof. u. Direktor der Laboratoriums für phys. u. org. Chemie an der Universität Giessen. Mit 8 Abbildungen in Text. 8vo, pp. 108. Halle a. S. Druck u. Verlag. von Wilhelm Knapp. 1902. (Price, M. 4.)

The rapidly growing literature devoted to electrochemistry is evidence of the rapid growth of the industry. Until recently the leading universities and technical schools here and abroad devoted either scant attention or none at all in their laboratories to electrochemical practice. Now, all this is changed.

The present work is intended as a laboratory guide for students in electrochemical practice, and the student is given a series of examples illustrating the several types of electrolytic decompositions and recompositions with inorganic and organic compounds. It is the first work that has come to our notice treating of the subject of electrolytic synthesis as a guide to the student, and we have no doubt that instructors in this branch of applied science have often severely felt the want of something of the kind. W.

A Manual of Photo-engraving, containing practical instructions for producing photo-engraved plates in relief-line and half-tones. By H. Jenkins. With supplementary chapters on the theory and practice of half-tone color work, by Frederic E. Ives and Stephen H. Horgan. Second edition. Chicago: The Miland-Procter Company, 1902. (Price, \$2.)

The present edition of this work has been thoroughly revised and brought up to date. The author gives full and explicit details of the various processes involved in the production of the several classes of photo-engravings, with a series of very instructive picture-illustrations.

The addition of a chapter by F. E. Ives on three-color-process theory and half-tone-process theory, and a thorough exposition of the practical workings of the three-color process, by Mr. S. H. Horgan, add to the value of the book. W.

Franklin Institute.

[*Proceedings of the Stated Meeting held Wednesday, November 19, 1902.*]

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, November 19, 1902.

President JOHN BIRKINBINE in the chair.

Present, 72 members and visitors.

Mr. Louis E. Levy offered the following resolution, which was duly adopted :

Resolved, That the Board of Managers be requested to appoint one or several delegates from its members at present residing or temporarily sojourning in Paris, to represent the Institute at a meeting of the Association of Inventors in France, and present a testimonial to M. Millerand, Ex-minister of Public Works, Posts and Telegraphs, for his services in promoting the amendment of the Patent Laws of France in the interest of inventors.

Mr. John S. Seymour, of New York, late U. S. Commissioner of Patents, presented a communication describing the acetone-acetylene system devised by Messrs. Claude and Hess, for the safe storage and transportation of acetylene, and exhibited the apparatus in operation.

The communication was freely discussed and, at the close of the discussion, the meeting passed a vote of thanks to the speaker of the evening.

Adjourned.

WM. H. WAHL, *Secretary*.

Committee on Science and the Arts.

[*Abstract of proceedings of the stated meeting held Monday, Nov. 5, 1902.*]

MR. THOS. P. CONARD in the chair.

The following reports were adopted :

(No. 2238.) *Electrical Distribution and Interior Wiring*.—Luther Stieringer, New York.

ABSTRACT.—The report considers in general terms a series of contributions to the art of electric illumination made by applicant, many of which are subjects of patents. These improvements cover principally systems of electrical distribution and interior wiring. Applicant's work was done at a time when no precedent had been established and forms the basis of the present system of fixture wiring and interior distribution, including what is known as the panel system of wiring.

The report alludes also to applicant's original work in decorative lighting, the installation of nearly all the large expositions held in this country having been carried out by him personally, or laid out on the lines suggested by his work.

The report concludes by recommending the award of the John Scott Legacy Premium and Medal to applicant "for his invention of insulating joints essential to combination fixtures for gas and electric light, for improvements in interior lighting and for the excellent information and descriptions

which he has given in connection with decorative lighting." [Sub-Committee.—W. C. L. Eglin, Chairman; Thomas Spencer, E. A. Scott.]

(No. 2214.) *National Machine Tool Company's System of Gearing*.—National Machine Tool Company, Cincinnati, O.

ABSTRACT.—This device is the invention of William L. Schellenbach, and consists of a method for rapidly and conveniently changing the gearing of screw-cutting lathes for cutting threads of various pitches. (Detailed description of the device is impracticable without the aid of illustrations).

The report concludes: "The device is very ingenious and materially facilitates the changing of ratio in screw-cutting, as a re-setting will occupy only a few minutes of time. Of course, exceptional cases will arise when an odd or unusual pitch is to be cut which does not happen to be within the list of possible combinations of the device. Recourse may then be had to a change of the gear-wheel on the screw and a re-clamping of the device on the lathe.

"The device is only adapted for lathes, on which the leadscrew is also used as a splined rod for the feed. On lathes having a separate splined rod the device is in the way of the feed-belt and cannot be permanently attached to the lathe. But in cases where it is applicable, your Committee considers it to be decidedly advantageous." The John Scott Legacy Premium and Medal is recommended to applicant. [Sub-Committee.—Hugo Bilgram, Chairman; Henry F. Colwin, Jacob Y. McConnell, Geo. S. Cullen.]

(No. 2207.) *Sectional Models for Stereometric Representation*.—W. C. F. Morsell, Philadelphia.

ABSTRACT.—After a careful study of the models and accompanying descriptive matter, the Committee expresses the opinion that they are well adapted to the illustration of sequence of form in the study of mensuration and solid geometry; that they demonstrate clearly the relation of the basal cubes to the solid forms derived by the use of cutting planes; and that these models can be made of especial value in manual training and other schools in which the study of the form can be supplemented by the construction of similar models by the individual pupil.

In consideration of this opinion, the report makes the award of the Edward Longstreth Medal of Merit to applicant. [Sub-Committee.—Geo. A. Hoadley, Chairman; Jos. W. Richards, L. F. Rondinella, Amos P. Brown.]

The following reports passed first reading, viz:

(No. 2257.) *Blue Printing*.—Sam'l Brent Whinery, Pittsburg, Pa.

(No. 2206.) *Turret Lathe*.—J. W. von Pillter, Leipzic-Gohlis, Germany.

(No. 2222.) *Theory of Musical Harmony*.—Victor Goldschmidt, Heidelberg, Germany.

(No. 2232.) *Process of Making Open-Hearth Steel*.—Benjamin Talbot, Philadelphia.

(No. 2235.) *Hydraulic Ram*,—Chas. C. Wentworth, Roanoke, Va.

(No. 2242.) *Electrolytic Process for Alkali and Bleach*.—Charles E. Acker, Niagara Falls, N. Y.

(No. 2251.) *Bridging Bell System for Telephones*.—John J. Carty, New York.

No. 2256.) *Acetylene Generator*.—G. P. Rush, Philadelphia.

(This was made advisory and adopted.)



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